Practicing Chiropractors’ Committee on Radiology Protocols (PCCRP) For Biomechanical Assessment Of Spinal Subluxation In Chiropractic Clinical Practice

Accepted for Inclusion in the National Guideline Clearinghouse July 2009

Official X-ray Guideline of the International Chiropractors Association (ICA)

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CHIROPRACTIC ENDORSING
ASSOCIATIONS & ORGANIZATIONS

Official Chiropractic X-ray Guidelines of the Following Associations/Organizations
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Only those having reviewed the PCCRP Guides and evaluated with the AGREE Instrument are listed.

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Preface

I. Preamble

The PCCRP Guidelines contained herein are evidence-based suggestions for appropriate radiographic evaluations of patients seeking chiropractic care. No guideline can replace the clinical decisions made by a chiropractic practitioner in the course of treating an individual patient’s health problem. Any approach, by a practitioner, that is different from the PCCRP Guidelines, does not necessarily mean that the approach in question was below the standard of care. However, any chiropractic practitioner, who adopts a course of action different from the PCCRP Guidelines, is advised to keep sufficient patient records to explain why such an action was undertaken.

Chiropractic is a philosophy, a science, and an art. From the state of any science (science is constantly evolving), the variety, complexity, severity, and intricacy of human health conditions create an environment where it is impossible to always have the appropriate examination, the appropriate radiographic analysis, and to predict with certainty the patient’s response to chiropractic spinal care. Therefore, adherence to these PCCRP Guidelines will not always insure that an accurate assessment of the patient’s spinal health has occurred. By following the PCCRP Guidelines, it is expected that the chiropractic practitioner will follow a reasonable course of action based on the best available knowledge. It is expected that with the assistance of the PCCRP Guidelines, the chiropractic practitioner will use the assessment of spinal subluxation suggested herein to deliver safe and effective chiropractic care.

II. Purpose/Aims, Clinical Questions, Patient Population, Intended Users

The purposes of these PCCRP Radiology Protocols are to (1) locate and rate the evidence for “Biomechanical Assessment of Spinal Subluxation in Chiropractic Clinical Practice Using Radiography” and (2) assist the practicing Chiropractor in making sound, fundamental clinical decisions when using radiology in clinical practice.

The aims of these Guidelines are nine-fold:

1. To provide evidence from the literature, identifying if the routine use of radiography in chiropractic practice, as mandated by State and Provincial laws, is valid practice,
2. To determine the health risk of spinal radiography use (see Section on Hormesis),
3. To identify the radiographic views utilized in most Chiropractic Technique systems,
4. To determine the clinical utility of common radiographic views for Chiropractic clinical practice,
5. To determine the reliability, validity, and efficacy of common radiological views utilized in chiropractic clinical practice,
6. To identify, with evidence, if the routine use of radiography in pediatric cases is valid,
7. To define chiropractic spinal subluxation from a structural/displacement view point and provide spinal radiographic normal values for alignment,
8. To review spinal radiographic guidelines from other professions, and
9. To provide Chiropractic College Instructors with the actual, updated, evidence on x-ray usage in Chiropractic clinical practice, in order that the current information be shared with prospective chiropractors.
Besides patients with headache, neck pain, thoracic pain, and low back pain, patients, who have been ‘medical failures’ with a variety of diseases and structural abnormalities, seek chiropractic care. For all these prospective patients, these PCCRP Guidelines outline the state of evidence for x-ray utilization in Chiropractic clinical practice.

Since a wide variety of suffering patients seek chiropractic care, and since chiropractic has a historical structural basis, the evaluation of spinal health, spinal degeneration, structural alignment, spinal balance, and how these affect health are among the clinical questions answered in this document.

These PCCRP Guidelines are intended to support the clinical decisions made by Practicing Chiropractors, not only in the USA and Canada, but in the world at large.

III. X-ray Protocols/Guidelines

While the whole document is the supporting evidence for routine radiographic examinations in clinical practice, in Section II, a list of Indications is actually the Guidelines (listed as “Indications for Spine Radiography in Children and Adults”). These Guidelines’/”Indications” for spine radiographic examinations include, but are not limited to:

1. Abnormal posture
2. Spinal Subluxation (as defined in this document)
3. Spinal deformity (eg, scoliosis, hyper-kyphosis, hypo-kyphosis)
4. Trauma, especially trauma to the spine
5. Birth Trauma (eg, forceps, etc…)
6. Restricted or abnormal motion
7. Abnormal gait
8. Axial pain
9. Radiating pain (eg, upper extremity, intercostal, lower extremity)
10. Headache
11. Suspected short leg
12. Suspected spinal instability
13. Follow-up for previous deformity, previous abnormal posture, previous spinal subluxation/displacement, previous spinal instability
14. Suspected osteoporosis
15. Facial pain
16. Systemic health problems (eg, skin diseases, asthma, auto-immune diseases, organ dysfunction)
17. Neurological conditions
18. Delayed developmental conditions
19. Eye and vision problems other than corrective lenses
20. Hearing disorders, vertigo, tinnitus
21. Spasm, inflammation, or tenderness
22. Suspected abnormal pelvic morphology
23. Post surgical evaluation
24. Suspected spinal degeneration/arthritis
25. Suspected Congenital anomaly
26. Pain upon spinal movement
27. Any “Red Flag Conditions” covered in previous guidelines.
IV. Guideline Development and Evaluation Process

A. Systematic Literature Search of Publications for the PCCRP Guidelines

1. Search Indices/Engines Used for Data Collection:
   - The Chiropractic, Orthopedic, Physical medicine, Osteopathic and Manual Medicine fields were searched using the following citation indices:
     a. Pub Med through Medline,
     b. MANTIS http://www.healthindex.com/,
     c. The Index to Chiropractic literature http://www.chiroindex.org/#results,
     d. Google’s beta version of their “scientific” search engine available for free use: http://www.scholar.google.com,
     e. Chiropractic and Orthopedic, and Radiology texts,
     f. Chiropractic technique texts.

2. Search Topics and Key Word Search
   - The search topics included the following:
     a. Radiography guidelines for spinal conditions.
     b. Radiation Hormesis, exposure levels, and health risks of radiation.
     c. Presence of pain as an indicator for spinal radiography.
        1) Which anatomical structures does the pain arise from?
           a) Disc.
           b) Facet joint & capsule.
           c) Other spinal ligaments.
           d) Muscles.
        2) Possible causes of pain?
           a) Chemical irritation.
           b) Abnormal mechanical loads on the spinal tissue.
        3) Possible causes of abnormal loads on the spinal tissues?
           a) Posture rotations & translations with spinal coupling.
           b) Sagittal buckling (snap through).
           c) AP buckling- Euler buckling.
           d) Segmental subluxations (retro, spondy, laterolisthesis).
     d. Definitions for spinal subluxation in Chiropractic:
        1) Key Words: Chiropractic, Subluxation Definitions, Subluxation Theories, Subluxation Categories, Spinal Lesion, Spinal Disfunction, and Vertebral Subluxation.
     e. X-ray views and procedures of the spine utilized in Chiropractic Practice:
     f. Reliability of X-ray measurement methods for spinal position:
G. Reliability/repeatability of X-ray positioning procedures of patients:

1) Key Words: Reliability, Repeatability, Posture, Spine Position Sense, Spine Position, Radiograph, Chiropractic Technique, Radiographic Analysis.

H. Predictive Validity of spinal displacements ascertained in different radiographic views:


I. Chiropractic, Physical Medicine, Osteopathic, Manual Medicine treatment outcome studies on spinal displacements verified by way of x-rays. Treatment method must be a known treatment as used in Chiropractic clinical practice and treatment must be used to reduce/correct spinal displacements on x-ray:

1) Key Words: Chiropractic Technique, Spinal Subluxation, Vertebral Subluxation, X-ray, Radiography, Radiograph.

III) Study Inclusion Criteria for Guideline Analysis and Production:

Studies were included if they fit the following criteria under each specific topic:

A) X-ray views of the spine utilized in Chiropractic Practice:

1) Any technique system or chiropractic technique text book or Chiropractic radiography text book describes the use of this view for analysis and measurement of spinal position or alignment.

J. Reliability of X-ray measurement methods for spinal position:

1) Study must have utilized a repeated measures design with at least one examiner measuring spinal position on a set of spinal x-rays at least twice.

2) Study must have reported a minimum of one of the following statistical analyses: standard error of measurement (SEM) or standard error of the mean, mean absolute value of observer(s) differences, intraclass correlation coefficients, interclass correlation coefficients, Pearson’s r value, Kappa coefficients.

K. Reliability/repeatability of X-ray positioning procedures of patients:

1) Study must have utilized a repeated measures design with at least one examiner ascertaining a spinal positional x-ray on a set of subjects at least twice.

2) Study must have reported a minimum of one of the following statistical analyses: standard error of measurement (SEM) or standard error of the mean, mean absolute value of observer(s) differences, intraclass correlation coefficients, interclass correlation coefficients, Pearson’s r value, Kappa coefficients.

L. Predictive validity of spinal displacements ascertained in different radiographic views:

1) Study must have ascertained spinal x-rays of any patient population that is specified as one of the following: Normal, Low back pain, Neck pain, Thoracic Pain, or other physical conditions related to the spine such as sciatica, disc degeneration, organ injury, health status, etc...

2) Study must have made measurements of spinal position using a reliable, radiographic procedure as outlined in #2 above.

3) Study must have made comparison of spinal alignment data from x-ray of healthy populations to spinal alignment data in ‘condition specific’ population.
4) If the study only utilized 1 group of subjects (low back pain, etc...), 1) study must have made an attempt to compare their data to data in other studies on other types of groups or 2) study must have attempted to break their subjects into severity of condition to look at spinal alignment correlations between these subject subsets.

M. Chiropractic, Physical Medicine, Osteopathic, Manual Medicine treatment outcome studies on spinal displacements verified by way of x-rays.

1) Treatment method must be a known treatment as used in Chiropractic Clinical Practice.

2) Treatment must be used to reduce/correct spinal displacements on x-ray.

3) Follow-up Radiography was utilized to document reduction in spinal subluxation/displacement.

4) Patient must have had a specified condition with one of the following outcome measurements in addition to radiography: 1) an acceptable positive orthopedic exam finding such as: range of motion, palpatory findings, pressure algometry, emg findings, etc...or 2) an acceptable patient outcome assessment such as: health status, quality of life score, NRS, VAS, Oswestry low back pain, etc...

B. Development of the PCCRP Guidelines and Review Process

1. Internal Drafting and Review

The PCCRP Guideline committee consists of 25 panel members. The first 5 of these members are the principal investigators:

Deed E. Harrison DC: Chair of the PCCRP Guidelines
Donald D. Harrison DC, PhD, MSE: Principal PCCRP Investigator
Christopher Kent, DC, JD: Principal PCCRP Investigator
Joseph Betz BS, DC: Principal PCCRP Investigator
Paul A. Oakley MS, DC: Principal PCCRP Investigator

Panel members were chosen based on their Chiropractic clinical practice experience, their position as educational experts in the Chiropractic profession, and/or their research publication experience in the Chiropractic sciences.

The 5 principal investigators met over the internet, performed preliminary literature searches as described above, and outlined the 13 respective sections of the PCCRP guidelines. The 5 principal investigators then asked the remaining 20 panel members to complete a given section or asked the panelist to choose a section that they had a primary knowledge and interest in. Each of the 13 Sections of the Guidelines was drafted by at least 2 panel members.

Upon completion of the initial PCCRP Guideline draft, all 25 members were asked to review the document in its entirety and complete a review form (See Appendix 1). All panel review forms were then analyzed by Harrison DE and Harrison DD and the PCCRP Guideline draft was revised accordingly. Following this 1st revision, all the panel members were then asked to review the PCCRP document again and complete a second review form (Appendix 1).

2. External Review

Following the 2 PCCRP Guideline panel draft reviews, the document was sent out for five phases of External Review. These five phases included:
a. Phase I: The PCCRP guideline was sent to a panel of International Chiropractic
reviewer/experts. These 10 members were independent of the PCCRP panel and were
from the United States (8 members), Ireland (1), New Zealand (1). The stipulation was
that these individuals had to be involved in 1 of the following areas: Clinical research and
private practice, Chiropractic Education at a CCE accredited Chiropractic College or
University, hold a secondary JD (law) degree in addition to their DC degree, Editor in
Chief of a peer-reviewed indexed Chiropractic research journal, and be in active clinical
practice and actively involved in a major Chiropractic ‘political’ organization. These 10
individual Chiropractic experts were asked to review and evaluate the PCCRP guidelines
with the AGREE Instrument.1

b. Phase II: A second set of independent chiropractic experts were sent the PCCRP
Guideline draft at the same time as those in Phase I. This second set of experts consisted
of chiropractors who simultaneously held Medical degrees. The stipulation was that the
individual had to have been in active Chiropractic clinical practice for at least 10 years
prior to attaining their Medical degree and switching their focus to active Medical
clinical practice. We identified 2 experts that fit these criteria. These 2 experts were
asked to review and evaluate the PCCRP guidelines with the AGREE Instrument.1

c. Phase III: At the same time as Phases I and II, the PCCRP guidelines were sent to
several major Chiropractic political associations and organizations for their review. The
political organizations that responded and have endorsed and adopted the PCCRP
guidelines as their official x-ray guidelines include:
   1. The International Chiropractors Association (ICA),
   2. The World Chiropractic Alliance (WCA),
   3. The Federation of Straight Chiropractors Organizations(FSCO),
   4. Council on Chiropractic Practice (CCP),
   5. Norway Chiropractic Association,
   6. Ukraine Chiropractic Association

d. Phase IV: At the same time as Phases I-III, the PCCRP guidelines were provided to the
many Chiropractic State Associations and Societies in the USA and several international
ones. The interested Chiropractic associations were asked to review the PCCRP
guidelines and provide relevant feedback with the evaluation instrument in Appendix 1.
The associations that responded and have adopted the PCCRP Guidelines as their official
association or society guidelines include:
   1. Arizona Chiropractic Society
   2. Chiropractic Awareness Council of Ontario
   3. Chiropractic Diplomatic Corps
   4. Chiropractic Fellowship of Pennsylvania
   5. Connecticut Chiropractic Council
   6. ICA-California (ICAC)
   7. ICA-Indiana (ICAI)
   8. Massachusetts Chiropractic Society
   9. Michigan Association of Chiropractors (MAC)
  10. Nevada Chiropractic Association
11. Virginia Society of Chiropractic
12. Washington State Chiropractic Association
13. Wyoming Chiropractic Society

e. Phase V: Following Phases I-IV, a website was set up (pccrp.org) where the guidelines were posted and open for review from the Chiropractic profession at large. The evaluation instrument in Appendix 1 was posted on the website and willing participants from the profession completed this form. The review process was open from September of 2006 through December 31st of 2007. As part of this profession wide review, the PCCRP Guides were sent to the Techniques in Chiropractic that utilize spinal radiography as a tool to aid in a working diagnosis for a given patient and for, in part, determining types and locations of adjustments and other interventions. This resulted in the following Chiropractic Named Techniques Endorsing the PCCRP Guides:

1. ASBE
2. Atlas Orthogonality
3. Blair
4. Chiropractic BioPhysics (CBP)
5. Gonstead
6. Grostic
7. NUCCA
8. Orthospinology
9. Pettibon
10. Toftness

Discussion

In each of the five Phases of PCCRP Guideline review and evaluation, the ‘evaluators’ were given a minimum of 4 weeks to complete their reviews. Following the completion of Phases I-IV of the external review process, the 5 principle investigators of the PCCRP evaluated all the submitted reviews. The validity and applicability of the comments/criticisms was evaluated and a consensus of at least 3/5 (a majority) of principal investigators was needed prior to altering/revising the draft of the PCCRP Guideline document. This was the 3rd draft of the document.

The fourth and final revision of the PCCRP Guideline occurred following the comments from the Chiropractic Profession at large in Phase V. The validity and applicability of the comments/criticisms was evaluated by the 5 principal investigators and a consensus of at least 3/5 (a majority) of principal investigators was needed prior to altering/revising the draft of the PCCRP Guideline document.

Thus, the PCCRP Guidelines underwent 4 primary draft revisions. This final draft is the completed version of the PCCRP Guideline.

3. PCCRP Guideline Review Outcomes


The Agree instrument has 6 domains and each domain can be scored by summing up all the scores of the individual items in a domain and by standardizing the total as a percentage of the
maximum possible score for that domain. The following 6 tables present the domain scores of the PCCRP Guideline from the ten international expert evaluators:

**Table 1. Domain 1 (Scope and Purpose):**

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</tr>
<tr>
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<td>4</td>
<td>4</td>
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</tr>
<tr>
<td>Reviewer 9</td>
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</tr>
<tr>
<td>Reviewer 10</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td>34</td>
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<td>35</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:**

\[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{114 - 30}{120 - 30} = 93.3\%
\]

**Table 2. Domain 2 (Stakeholder Involvement):**

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
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<td>1</td>
<td>4</td>
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</tr>
<tr>
<td>Reviewer 2</td>
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<tr>
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</tr>
<tr>
<td>Reviewer 4</td>
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</tr>
<tr>
<td>Reviewer 5</td>
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</tr>
<tr>
<td>Reviewer 6</td>
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<tr>
<td>Reviewer 7</td>
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<tr>
<td>Reviewer 8</td>
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<tr>
<td>Reviewer 9</td>
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<td><strong>Total</strong></td>
<td>39</td>
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<td>40</td>
<td>33</td>
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</tbody>
</table>

**Standardized Domain Score:**

\[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{141 - 40}{160 - 40} = 84\%
\]

**Table 3. Domain 3 (Rigour of Development):**

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Item 5</th>
<th>Item 6</th>
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<td>3</td>
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<tr>
<td>Reviewer 4</td>
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<td>4</td>
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<tr>
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<td>4</td>
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<td>4</td>
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<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 6</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 7</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Reviewer 8</td>
<td>4</td>
<td>4</td>
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Table 4. Domain 4 (Clarity and Presentation):

<table>
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<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Total</th>
</tr>
</thead>
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<tr>
<td>Reviewer 2</td>
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<tr>
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<td>Reviewer 9</td>
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<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Reviewer 10</td>
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<td>4</td>
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<td><strong>Total</strong></td>
<td>40</td>
<td>37</td>
<td>37</td>
<td>151</td>
</tr>
</tbody>
</table>

Standardized Domain Score: \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} \times 100 = \frac{151 - 40}{160 - 40} \times 100 = 92.5%.
\]

Table 5. Domain 5 (Applicability):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Reviewer 2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 6</td>
<td>3</td>
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</tr>
<tr>
<td>Reviewer 7</td>
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<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Reviewer 8</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 9</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Reviewer 10</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>34</td>
<td>37</td>
<td>35</td>
</tr>
</tbody>
</table>

Standardized Domain Score: \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} \times 100 = \frac{106 - 30}{120 - 30} \times 100 = 84.4%.
\]

Table 6. Domain 6 (Editorial Independence):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Reviewer 2</td>
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<td>4</td>
</tr>
<tr>
<td>Reviewer 3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 1</td>
<td>Reviewer 2</td>
<td>Reviewer 3</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

**Standardized Domain Score:**  
\[
\text{Obtained Score - Min. Possible Score} = \frac{\text{Max. Poss. Score - Min. Possible Score}}{\text{Max. Poss. Score - Min. Possible Score}} \\
\text{77 - 20} = 95\% \\
80 - 20
\]

**Table 7.** Overall Guideline Assessment: Would you recommend these guidelines for use in practice?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Recommend</th>
<th>Recommend with provisos or alterations</th>
<th>Would not recommend</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewer 2</td>
<td></td>
<td>X</td>
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<td></td>
</tr>
<tr>
<td>Reviewer 3</td>
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<tr>
<td>Reviewer 4</td>
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<td>Reviewer 5</td>
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<td>Reviewer 8</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reviewer 10</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**B. Expert Reviewers Holding Both a Chiropractic Degree and a Medical Degree**

The following 6 tables present the domain scores of the PCCRP Guideline from the two Chiropractic and Medical expert evaluators:

**Table 1.** Domain 1 (Scope and Purpose):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 2</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8</strong></td>
<td><strong>8</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

**Standardized Domain Score:**  
\[
\text{Obtained Score - Min. Possible Score} = \frac{\text{Max. Poss. Score - Min. Possible Score}}{\text{Max. Poss. Score - Min. Possible Score}} \\
\text{23 - 6} = 94.4\% \\
24 - 6
\]
### Table 2. Domain 2 (Stakeholder Involvement):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:** \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{29 - 8}{32 - 8} = 87.5\%
\]

### Table 3. Domain 3 (Rigour of Development):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Item 5</th>
<th>Item 6</th>
<th>Item 7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
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<td>8</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>51</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:** \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{51 - 14}{56 - 14} = 88\%
\]

### Table 4. Domain 4 (Clarity and Presentation):

<table>
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<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Reviewer 2</td>
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<td>2</td>
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<td>2</td>
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<tr>
<td><strong>Total</strong></td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:** \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{25 - 8}{32 - 8} = 70.8\%
\]

### Table 5. Domain 5 (Applicability):

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
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<th>Total</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td>6</td>
<td>7</td>
<td>20</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:** \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{20 - 6}{24 - 6} = 77.7\%
\]

### Table 6. Domain 6 (Editorial Independence):

<table>
<thead>
<tr>
<th>Item 1</th>
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</tr>
</thead>
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<tr>
<td>Reviewer 2</td>
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<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

**Standardized Domain Score:** \[
\frac{\text{Obtained Score} - \text{Min. Possible Score}}{\text{Max. Poss. Score} - \text{Min. Possible Score}} = \frac{14 - 4}{16 - 4} = 83.3\%
\]
Table 7. Overall Guideline Assessment: Would you recommend these guidelines for use in practice?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Recommend</th>
<th>Recommend with provisos or alterations</th>
<th>Would not recommend</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer 1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewer 2</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Open Review from the Chiropractic Profession

Due to the length of the PCCRP Guideline, the committee members agreed to extend the profession wide evaluation period for nearly 1.5 years; from August 8th of 2006 through December 31st of 2007. Over this interval, 806 unique Chiropractors attempted to complete the survey instrument in Appendix I evaluating the PCCRP Guideline. Only fully completed surveys were accepted by the website resulting in 793 unique surveys completed from practicing Chiropractors profession wide. The following 14 tables show the results of the profession wide survey for each of the 14 PCCRP Guideline Sections.

1) Section I External Review Evaluation ‘Instrument’ for the PCCRP Guidelines

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>750</td>
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</tr>
<tr>
<td>Somewhat Agree</td>
<td>30</td>
<td>(3.73%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>5</td>
<td>(0.62%)</td>
</tr>
<tr>
<td>Somewhat Disagree</td>
<td>0</td>
<td>(0.00%)</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>8</td>
<td>(0.99%)</td>
</tr>
</tbody>
</table>

2) Section II External Review Evaluation ‘Instrument’ for the PCCRP Guidelines

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>749</td>
<td>(93.04%)</td>
</tr>
<tr>
<td>Somewhat Agree</td>
<td>29</td>
<td>(3.60%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>6</td>
<td>(0.75%)</td>
</tr>
<tr>
<td>Somewhat Disagree</td>
<td>0</td>
<td>(0.00%)</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>9</td>
<td>(1.12%)</td>
</tr>
</tbody>
</table>

3) Section III External Review Evaluation ‘Instrument’ for the PCCRP Guidelines

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>749</td>
<td>(93.04%)</td>
</tr>
<tr>
<td>Somewhat Agree</td>
<td>29</td>
<td>(3.60%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>5</td>
<td>(0.62%)</td>
</tr>
<tr>
<td>Somewhat Disagree</td>
<td>2</td>
<td>(0.25%)</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>8</td>
<td>(0.99%)</td>
</tr>
<tr>
<td>4) Section IV External Review Evaluation 'Instrument' for the PCCRP Guidelines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td></td>
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</tr>
<tr>
<td><strong>Strongly Agree</strong></td>
<td>753</td>
<td>(93.54%)</td>
</tr>
<tr>
<td><strong>Somewhat Agree</strong></td>
<td>27</td>
<td>(3.35%)</td>
</tr>
<tr>
<td><strong>Neutral</strong></td>
<td>5</td>
<td>(0.62%)</td>
</tr>
<tr>
<td><strong>Somewhat Disagree</strong></td>
<td>0</td>
<td>(0.00%)</td>
</tr>
<tr>
<td><strong>Strongly Disagree</strong></td>
<td>8</td>
<td>(0.99%)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>5) Section V External Review Evaluation 'Instrument' for the PCCRP Guidelines</th>
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<tbody>
<tr>
<td><strong>Strongly Agree</strong></td>
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<tr>
<td><strong>Somewhat Agree</strong></td>
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<tr>
<td><strong>Neutral</strong></td>
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<tr>
<td><strong>Somewhat Disagree</strong></td>
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<tr>
<td><strong>Strongly Disagree</strong></td>
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<thead>
<tr>
<th>6) Section VI External Review Evaluation 'Instrument' for the PCCRP Guidelines</th>
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<td><strong>Strongly Agree</strong></td>
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<tr>
<td><strong>Neutral</strong></td>
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<tr>
<td><strong>Somewhat Disagree</strong></td>
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<tr>
<td><strong>Strongly Disagree</strong></td>
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<th>7) Section VII External Review Evaluation 'Instrument' for the PCCRP Guidelines</th>
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<td><strong>Strongly Agree</strong></td>
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<tr>
<td><strong>Neutral</strong></td>
</tr>
<tr>
<td><strong>Somewhat Disagree</strong></td>
</tr>
<tr>
<td><strong>Strongly Disagree</strong></td>
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<th>8) Section VIII External Review Evaluation 'Instrument' for the PCCRP Guidelines</th>
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<td><strong>Strongly Agree</strong></td>
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<td><strong>Somewhat Agree</strong></td>
</tr>
<tr>
<td><strong>Neutral</strong></td>
</tr>
<tr>
<td><strong>Somewhat Disagree</strong></td>
</tr>
<tr>
<td><strong>Strongly Disagree</strong></td>
</tr>
<tr>
<td>9) Section IX External Review Evaluation 'Instrument' for the PCCRP Guidelines</td>
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<td>----------------------------------</td>
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<td>Strongly Agree</td>
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<tr>
<td>Somewhat Agree</td>
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<tr>
<td>Neutral</td>
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<tr>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>Strongly Disagree</td>
</tr>
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</table>

| 10) Section X External Review Evaluation 'Instrument' for the PCCRP Guidelines |
|----------------------------------|-----------------|-----------------|
| Strongly Agree                   | 750             | (93.17%)        |
| Somewhat Agree                   | 26              | (3.23%)         |
| Neutral                          | 8               | (0.99%)         |
| Somewhat Disagree                | 0               | (0.00%)         |
| Strongly Disagree                | 8               | (0.99%)         |

| 11) Section XI External Review Evaluation 'Instrument' for the PCCRP Guidelines |
|----------------------------------|-----------------|-----------------|
| Strongly Agree                   | 737             | (91.55%)        |
| Somewhat Agree                   | 39              | (4.84%)         |
| Neutral                          | 8               | (0.99%)         |
| Somewhat Disagree                | 1               | (0.12%)         |
| Strongly Disagree                | 7               | (0.87%)         |

| 12) Section XII External Review Evaluation 'Instrument' for the PCCRP Guidelines |
|----------------------------------|-----------------|-----------------|
| Strongly Agree                   | 756             | (93.91%)        |
| Somewhat Agree                   | 23              | (2.86%)         |
| Neutral                          | 5               | (0.62%)         |
| Somewhat Disagree                | 0               | (0.00%)         |
| Strongly Disagree                | 8               | (0.99%)         |

| 13) Section XIII External Review Evaluation 'Instrument’ for the PCCRP Guidelines |
|----------------------------------|-----------------|-----------------|
| Strongly Agree                   | 754             | (93.66%)        |
| Somewhat Agree                   | 22              | (2.73%)         |
| Neutral                          | 7               | (0.87%)         |
| Somewhat Disagree                | 1               | (0.12%)         |
| Strongly Disagree                | 8               | (0.99%)         |
14) Section XIV External Review Evaluation 'Instrument' for the PCCRP Guidelines

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<table>
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<tr>
<td>Strongly Agree</td>
<td>754</td>
<td>(93.66%)</td>
</tr>
<tr>
<td>Somewhat Agree</td>
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<td>(2.73%)</td>
</tr>
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<td>Neutral</td>
<td>7</td>
<td>(0.87%)</td>
</tr>
<tr>
<td>Somewhat Disagree</td>
<td>1</td>
<td>(0.12%)</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>8</td>
<td>(0.99%)</td>
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V. Possible Stake Holders’ Conflicts of Interest

A. Introduction

According to Linton & Peachy, “Guidelines must emanate from a credible and acceptable source. Governments do not qualify on either ground.” Additionally, “The second group of non-medical organizations that might attempt to impose standards includes third-party payers, insurance groups, and, perhaps hospital administrative organizations.”

In an article published in JAMA investigating potential conflict of interest of authors of Clinical Practice Guidelines (CPG’s), Chaudrey stated, “if individual authors have relationships that pose a potential conflict of interest, readers of these CPG’s may wish to know about them to evaluate the merit of those guidelines.” The author continues, “Financial conflicts of interest for authors of CPGs are of particular importance since they may not only influence the specific practice of these authors but also those of the physicians following the recommendations contained within the guidelines.”

Eccles is quoted as stating, “There are good theoretical reasons to believe that individuals’ biases are better balanced in multidisciplinary groups, and that such balance will produce more valid guidelines.” A “Multidisciplinary” composition for a guideline of the nature of the current PCCR Guidelines (for the chiropractic profession) does not imply the inclusion of medical and/or osteopathic physicians. Rather, we believe that a more representative group of chiropractic researchers and clinicians, whose primary focus was/is clinical treatment of patient conditions as chiropractic clinicians either currently or in the past, is most appropriate.

In discussing the biases and conflicts in evidence based medicine (EBM) and CGP development, Arnett stated:

“...the most important problem with EBM is that of its ethics. EBM is not a physician driven agenda. It has bypassed the clinicians (those physicians with clinical training, experience, and an extensive knowledge of health and disease) in favor of an alliance of managers and their statistical technocrats, who are empowered to define ‘best practices’, and “Their paychecks depend on churning out these definitions. These non-clinicians thus have acquired substantive influence over millions of clinical consultations without sharing any of the responsibility for the clinical consequences.”

Based upon this information, the 5 PCCRP principal investigators sought to develop radiology guidelines for the Chiropractic profession that were driven by chiropractic clinicians’ understanding of the individual patient needs on one hand and an extensive knowledge of the scientific literature relating to spinal health and pain disorders on the other. Input from 3rd party payors, government agencies, managed care organizations and the like were not sought and not
considered relevant. Involvement of chiropractic independent medical evaluators (IME’s) for insurance providers was minimized with only 2/25 individuals from the PCCRP having this designation. Involvement from chiropractic technique leaders and individuals who teach continuing education conferences for licensure renewal in the chiropractic profession were not considered to be conflicts of interest.

None of the 25 PCCRP panel members received funding of any kind for their involvement in the PCCRP Guidelines. However, because Chaudry stated, “Unfortunately, bias may occur both consciously and subconsciously, and therefore, its influence may go unrecognized”3; it is necessary to list and describe all possible conflicts of interest of all PCCRP panel members.

B. The 5 PCCRP Principal Investigators:

<table>
<thead>
<tr>
<th>Name</th>
<th>PCCRP Section Involved</th>
<th>IME: Yes/No</th>
<th>Years Active Clinical Practice:</th>
<th># of Peer-Reviewed Publications</th>
<th>Chiropractic Technique Leader and/or CE Instructor</th>
<th>Reviewer Peer-Reviewed Journal</th>
<th>Member to Chiropractic Organization</th>
<th>Previous CPG Panel Member</th>
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</thead>
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<tr>
<td>Harrison, DE</td>
<td>All</td>
<td>No</td>
<td>9, Active</td>
<td>75 plus</td>
<td>CBP Technique CE Instructor</td>
<td>Spine, Eur Spine J, Clin Biom, Clin Anat, APM&amp;R</td>
<td>ICA, NV Rep</td>
<td>No</td>
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<tr>
<td>Harrison, DD</td>
<td>All</td>
<td>No</td>
<td>15, Inactive Now</td>
<td>70 plus</td>
<td>CBP Technique CE Instructor</td>
<td>JMPT</td>
<td>ICA, WY Rep &amp; Board Member</td>
<td>No</td>
</tr>
<tr>
<td>Kent, C</td>
<td>All</td>
<td>No</td>
<td>16, Inactive Now</td>
<td>20</td>
<td>Yes, CE Instructor</td>
<td>Yes, 2 Journals</td>
<td>WCA Board Member</td>
<td>CCP Guidelines</td>
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<td>Betz, J</td>
<td>II, V, VI, VIII, IX, X, XI, XII</td>
<td>No</td>
<td>5, Active</td>
<td>10 publications</td>
<td>No</td>
<td>No</td>
<td>ICA, ID Rep</td>
<td>No</td>
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<tr>
<td>Oakley, P</td>
<td>II, V, VI, VII, X</td>
<td>No</td>
<td>3, Active</td>
<td>2 publications</td>
<td>No</td>
<td>No</td>
<td>Ontario Chiropractic Assoc.</td>
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</table>

Discussion

The 5 principal PCCRP guideline investigators do not have any disabling conflicts of interest. The only possible ‘perceived’ conflict of interest would be the relationship of 2/5 to a specific named technique (Harrison DE and Harrison DD). However, how can the ties to a named technique influence the desire to utilize radiography in clinical chiropractic practice? The utilization of spinal radiography is influenced by physician training, experiences, personal views/biases, and personal knowledge. The two individuals tied to a named technique are two of the leading chiropractic researchers in the profession. They have extensive knowledge in the scientific literature and are reviewers for a combined 6 different peer-reviewed spine journals. Lastly, Harrison DD, holds advanced degrees in the field of mathematics and mechanical engineering, both of which fields have relevance to radiography assessment of spinal structure/position.

One individual has previously chaired the development of a Chiropractic CPG known as the CCP Guidelines (Kent, C). However, this was/is an asset due to his extensive knowledge of
the CGP guideline development process and the chiropractic literature in general. Furthermore,
this individual is a leading chiropractic research investigator, is a reviewer for two peer-reviewed
spine journals, and holds a secondary law (JD) degree. The fact that this individual holds a
secondary law degree and is a licensed attorney was considered a great asset in developing the
PCCRP guidelines.

Four out of 5 principal investigators are affiliated with large chiropractic professional
organizations. This was not considered to be a conflict of interest and is/was in fact an asset.
These political organizations represent a large number of practicing chiropractors and thus their
needs and their patients’ needs are likely to be considered in the PCCRP Guidelines.
Furthermore, the affiliation with large chiropractic professional organizations adds validity to the
PCCRP guidelines as it has the endorsement of these groups and does not simply come from
chiropractic clinicians with ‘their own agendas’.

Lastly, all 5 members of the PCCRP guidelines have been (Kent, C and Harrison DD) in
private practice or are currently in active private practices, all 5 members are research
investigators in the chiropractic sciences, and 3/5 hold dual advanced degrees in professional
fields that are related to the PCCRP Guideline sections (Oakley P, in biomechanics).

C. The 20 Secondary PCCRP Panel Members:

Table 2.
   Possible Conflicts of Interest for 20 Secondary PCCRP Guideline Panel Members.

<table>
<thead>
<tr>
<th>Name</th>
<th>PCCRP Section Involved</th>
<th>IME: Yes/No</th>
<th>Years Clinical Practice:</th>
<th>Peer-Reviewed Publications</th>
<th>Chiropractic Technique Leader and/or CE Instructor</th>
<th>Reviewer Peer-Reviewed Journal</th>
<th>Member to Chiropractic Organization</th>
<th>Previous CPG Panel Member</th>
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<tr>
<td>Peet, J</td>
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<td>CE Instructor</td>
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<td>Anderson-Peacock, L</td>
<td>XI</td>
<td>No</td>
<td>20, Active</td>
<td>Yes, several</td>
<td>CE Instructor</td>
<td>JVSР</td>
<td>OCA, CCA, ICA, WCA, ICPA, CAC</td>
<td>Yes, CGP Canada</td>
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<tr>
<td>Colloca, CJ</td>
<td>XII</td>
<td>Yes, &lt;1 per year</td>
<td>10, Active</td>
<td>Yes, &gt;40</td>
<td>Yes, 21st Century Chiropractic Training; CBP Instructor</td>
<td>Chiro &amp; Osteopath, Eur Spine Journal, J Biomech, Spine</td>
<td>ACA, AZ Chiro Assoc, AZ Chiro Society, CBP NP, ICA, WFC</td>
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<tr>
<td>Murphy, D</td>
<td>II, X, XII</td>
<td>No</td>
<td>Yes, CE Instructor</td>
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<td>No</td>
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<td>Molyneaux, E</td>
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<tr>
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<td>CBP Technique</td>
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<td>ICA, WY Rep</td>
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<td>Siskin, L</td>
<td>VII, X</td>
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<td>9, Active</td>
<td>2</td>
<td>CBP Instructor</td>
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<td>Davis, CG</td>
<td>II, V, VI, VII, VIII, X, XI</td>
<td>No</td>
<td>19, Active</td>
<td>Yes, CE Instructor</td>
<td>Yes, Clin Drug Invest, J Muscul Pain</td>
<td>ICA</td>
<td>ICA, ICAC</td>
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<td>25, Active</td>
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<td>No</td>
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<td>ICA</td>
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</table>
### Discussion

The only different possible conflicts of interest that the secondary panel members have, compared to the principal investigators is that 3/21 are IME’s. Regarding the 2 individuals (Makos BK and Bacso SN) that hold full time positions as IME’s, these individuals were sought due to their previous involvement in a CGP (the Glen Erin guidelines) and due to their expertise in motion x-ray technology and assessment. However, the section (X-F) that these panel members drafted was independently drafted by 2 other panel members as well; 2/5 (Harrison DE and Betz J) of the principal investigators compiled the final draft of section X-F by combining these two drafts and adding further scientific sources prior to arriving at any recommendations.

### VI. Proposed Procedure for Updating the PCCRP Guideline

Since the PCCRP Guideline Chair, Deed E. Harrison, DC is 37 years old (2009), he will continue to act as chair over the next 5-year interval. An annual committee meeting, proposed for each January of 2010-14, will be held either online through relevant meeting venues or at an agreed upon conference location. At these meetings, committee members will disperse, read and evaluate newly published articles concerning the PCCRP Guideline topics from literature searches performed in the previous year.

From that point forward, Dr. Deed Harrison, Dr. Joe Betz, Dr. Christopher Kent, and Dr. Paul Oakley will identify and outline potential areas of the PCCRP Guideline to be updated based on the new information. Since it is suggested that guidelines be updated at least every 5 years, in 2014, we will revise and update all the relevant sections of the PCCRP Guideline information.

Over the interval from years 2014 through 2019, we anticipate the above process to be ongoing, however, a different Chair may be voted and different committee members may be sought.
Appendix 1. Internal Review ‘instrument’ sent to PCCRP Guideline Panelists

Table 1
Please Mark an “X” in the appropriate Column
My Name is ____________________(Important for Statistics to be accurate)

<table>
<thead>
<tr>
<th>Section #</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
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We value your comments, but we need these by Section #. Thus notice that as you type in the following Table 2, the row height will increase allowing you to type as much as you wish, but at the same time allowing us to keep comments by Section #. Please be direct/brief in your comments.

Table 2. Specific Section Criticism/Comments

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<th>Section #</th>
<th>My Comments on each section are entered below. If you have no additional comments, please just type in “AGREE”</th>
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</thead>
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References


I. Description of Levels of Evidence, Grades and Recommendations

Introduction

Recently, the buzzwords ‘evidence-based,’ ‘evidence-based medicine’ (EBM), and ‘evidence-based practice’ (EBP) have appeared in clinical practice protocols. EBP is defined as clinical decision-making based on (1), sound external research evidence combined with individual clinical expertise and (2), the needs of the individual patient. The goal of EBP is to improve patient outcomes, quality of care, and provide some standardization of treatment. EBP protocols have recently been written for several conditions.

One of the issues being debated is ‘what does and what does not provide evidence in EBM.’ Understanding the relevance and weight of evidence is an important topic when creating evidence based guidelines. The current guidelines seek to draw on the research and evidence in relation to the chiropractic utilisation of x-rays. Hence while some considerations will be to look at general evidence from across the health care and radiation science spectrum, specific evidence in relationship to chiropractic x-ray utilisation will be a primary consideration.

When reviewing a volume of evidence on a particular topic, it is important to understand, that there are different levels of evidence, i.e. that not all forms of evidence can be considered of equal value. However, of equal importance, it also needs to be stated that all levels of evidence are important and have their respective value. It is widely accepted in the scientific and health care community that there are four levels of clinical treatment evidence. Depending on which organisation’s guideline we look at, there are subtle variations however the basic characterizations are the same:

- **Level 1.** Randomized controlled trials—including quasi-randomized processes such as alternate allocation.

- **Level 2.** Non-randomized controlled trial—a prospective (pre-planned) study, with predetermined eligibility criteria and outcome measures.

- **Level 3.** Observational studies with controls—including retrospective, interrupted time series (a change in trend attributable to the intervention), case-control studies, cohort studies with controls, and health services research that includes adjustment for likely confounding variables.

- **Level 4.** Observational studies without controls (e.g., cohort studies without controls, case series without controls, and case studies without controls).


Or

1. **Level I:** Randomized controlled trials. This is generally accepted as the most reliable evidence of whether a treatment is effective.

2. **Level II (a):** Good studies with a non-randomized control group (case/control or cohort). Prospective data or case notes, similar groups, correcting for confounding in the analysis.
3. **Level II (b):** Poor studies with a non-randomized control group (case/control or cohort). Data gathered after the event, poorly matched groups, and no attempt to correct for confounding variables.

4. **Level III:** Studies with no control group. Case series, anecdote, and testimonial.

(Source: Department of Public Health Sciences King's College London
http://phs.kcl.ac.uk/teaching/ClinEpid/Evidence.htm)

Or

- **Level I:** Evidence obtained from at least one properly designed randomized controlled trial.
- **Level II-1:** Evidence obtained from well-designed controlled trials without randomization.
- **Level II-2:** Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one centre or research group.
- **Level II-3:** Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled trials could also be regarded as this type of evidence.
- **Level III:** Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.

**Discussion**

When we consider the evidence from the chiropractic field, we cannot exclusively or even primarily restrict evidence to RCTs. As chiropractic is a clinical based science with few allied industries willing to invest into research, i.e. as pharmaceutical companies do in medicine, the most prevalent type of research in chiropractic is non-randomized clinical trials, case series, and case studies. The highest of these have control groups and there are a select few that also have randomized control groups. The main reasons for lack of RCTs in chiropractic research include labour intensiveness, cost, usually restricted to university research groups, and in the chiropractic field, there is not the tradition of research at a university level as there is in other health sciences.

In order to create a guideline that is truly evidenced based but still relevant to the chiropractic profession, all levels of evidence need to be considered. In some cases, chiropractic guideline developers have excluded specific types or levels of evidence for unknown reasons.13

In 2001, Bolton1 discussed the reliance on RCT’s in EBP protocols. Although the first few published RCTs on spinal manipulative therapy (SMT) were important for the chiropractic profession, RCTs are many times narrow in methodology as to not be useful in clinical chiropractic practice.1,14 Although the RCT is unarguably the best research design for investigating a specific intervention compared to a known intervention or a placebo, “randomization and controlled conditions play no part in everyday clinical practice”1 and thus, evidence for effectiveness in that arena cannot be solely collected by RCTs. The strengths and limitations of the RCT have been discussed elsewhere.15

Given the limitations of the RCT in evaluating chiropractic treatment,14 it has been stated that it does not make sense to exclusively pursue the RCT in the future.16 Other research designs such as qualitative and outcomes research are now being recognized as very meaningful ways of...
providing the evidence in EBP. Additionally, it is known today that well-done case studies most often demonstrate findings consistent with that of the RCT. For examples:

1. Benson and Hartz stated, “We found little evidence that estimates of treatment effects in observational studies reported after 1984 are either consistently larger than or qualitatively different from those obtained in randomized, controlled trials.” And

2. Rosner stated, “From this discussion, it is apparent that a well crafted cohort study or case series may be of greater informative value than a flawed or corrupted RCT.” And,

3. Concato et al stated, “The results of well-designed observational studies (with either a cohort or a case-control design) do not systematically overestimate the magnitude of the effects of treatment as compared with those in randomized, controlled trials on the same topic.” And, “The popular belief that only randomized, controlled trials produce trustworthy results and that all observational studies are misleading does a disservice to patient care, clinical investigation, and the education of health care professionals.”

The above review delineating the relevance of observational studies has significance to the chiropractic profession in as much that the ‘birth’ of the chiropractic profession was based on a case report by Daniel David Palmer. In other words, if not for the case report, the chiropractic profession might not exist as we know it today.

Levels of Evidence for The Current Document

There are many different types of clinical studies, which may be used to obtain evidence that a certain procedure or set of procedures is effective. We have listed some of the common clinical studies in order of their importance, i.e., item #1 is lower evidence than item #2, etc. It is noted that the Non-randomized Clinical Control Trial (#9) and the Randomized Clinical Control Trial (#10) are the highest forms of clinical evidence. Definitions for these types of clinical studies can be found on the internet and the majority of these definitions are provided at the end of this section. The current PCCRP Guidelines for clinical chiropractic practice, will consider all of the following types of clinical studies as evidence:

1. Cost-Benefit or Cost-Effectiveness Analysis,
2. Case Study (Single Subject Experimental Design),
3. Case-Control Study (Case-Referent or Case-Comparison Study),
4. Case Series,
5. Cohort,
6. Inception Cohort,
7. Cohort Analytic Study,
8. Crossover Trial,
9. Nonrandomized Control Trial,
10. Randomized Control Trial,

With the background information presented above, it is obviously important to include all types of evidence. However, it is often forgotten that clinical studies are not the only types or categories of evidence. Some of these other categories of evidence are (but not limited to):

1. Basic Science studies, including but not limited to:
   a. Spinal modeling
   b. Evaluations of loads, Stresses, & Strains
   c. Normal & abnormal anatomy
669  d. Physiology
670  e. Pathological processes,
671  2. Spinal alignment & Health studies (e.g., correlation studies),
672  3. Mechanical evaluations of medical/surgical devices,
673  4. Reliability and validity studies on clinical devices/procedures;
674  5. Professional Surveys.
675
676 **Classifications & Ratings of Evidence**
677  Sackett is generally referred to as the father of evidence-based medicine. The goal of
678  “Evidence-Based Medicine” (EBM) or “Evidence-Based Practice” (EBP) is to improve patient
679  outcomes, quality of care, and provide some standardization of treatment. Sackett defined
680  “evidence-based practice” (EBP) as, “The conscientious, explicit, and judicious use of the
681  current best evidence in making decisions about the care of individual patients.” He also stated
682  that EBP “is not restricted to randomized trials and meta-analyses. It involves tracking down the
683  best external evidence with which to answer our clinical questions.”
684  For clinical treatments, the 10 types of clinical studies were previously defined. To determine
685  the “best evidence”, systematic reviews of available published evidence are required. The value
686  of these literature reviews, however, depends on the quality of the review (selection bias by
687  those doing the review), the quality of the publications, and how these are rated by any
688  committee commissioned to evaluate the “evidence”. Often, EBM and EBP guidelines only use
689  evidence from controlled trials, which is not what Sackett proposed.
690  In any healthcare discipline, to have RCTs as evidence on all treatment methods is
691  impossible. Because of the limited number and selectiveness of available RCTs, there has been
692  much criticism of the abuses of EBM and EBPs. In 1997, Kahn et al. stated that, for
693  evidence-based practice guidelines (EBGs) to be useful, they need to consider all the best
694  evidence, including that from controlled trials, case series, and case reports, and they must allow
695  for clinical experience and judgment. We reiterate that well-done case studies and series most
696  often demonstrate findings consistent with that of the RCT.
697  In fact, Lattuv stated that EBM represents a convergence of financial interests, including
698  Managed Care Organizations (MCOs), which want practice guidelines to control costs and
699  maximize profits. He stated that there is a “diminishing role of practicing physicians in shaping
700  medical policies.”
701  Since MCOs use EBGs to decide coverages, Latov went on to state that it is foolish to think
702  that EBP guidelines do not restrict options. “Behind the facade of EBGs, MCOs can determine
703  medical policy with impunity.”
704
705 **PCCRP Guidelines Classification of Evidence**
706  In order to classify levels of evidence for the different categories listed above, it was
707  necessary to derive the following table of “Classifications of Evidence”. To use these Classes of
708  Evidence, one must identify the Type of study, and then classify it according to the following
709  table, e.g., Type = Reliability, Classification = Class 1-2. All types of studies were considered in
710  developing the PCCRP Guidelines and none were excluded.
Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
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<td>≤ 30 subjects</td>
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<td><strong>Professional Surveys</strong></td>
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</table>

PCCRP Guidelines Ratings of Evidence

The Center for Evidenced Based Medicine (CEBM) describes “Levels of Evidence” as having essentially originated when Suzanne Fletcher and Dave Sackett were working for the Canadian Task Force on the Periodic Health Examination in the late 1970’s. They introduced "levels of evidence" for ranking the validity of “evidence”. They then submitted "grades of recommendations" (A-D) to the advice given in the report, based upon the extent of evidence reviewed. The PCCRP Guidelines will use the “grades of recommendation” put forth by Phillips et al, but will slightly modify these to fit the non-clinical levels of evidence. See Table 2.
In the Grades of recommendations in Table 2, it is possible to classify all the clinical and scientific publications that the PCCRP panel sought as possible evidence for our PCCRP Guidelines. Thus, all types and levels of evidence were considered, not just the RCT.

Table 2. Grades of Recommendation from Phillips et al.29

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>Grades A-D</th>
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</thead>
<tbody>
<tr>
<td>Clinical Level I</td>
<td>A= Consistent Level I Studies or A Systematic Review (SR) or Meta-Analysis (MA)</td>
</tr>
<tr>
<td>Clinical Level II</td>
<td>B= Consistent Level II Studies or A Single Level I Study</td>
</tr>
<tr>
<td>Clinical Level III</td>
<td>B= Consistent Level III Studies</td>
</tr>
<tr>
<td>Clinical Level IV</td>
<td>C= Consistent Level IV Studies or Extrapolations from Level II or III</td>
</tr>
<tr>
<td>Expert Opinion V</td>
<td>D= Level V Evidence or Inconsistent Studies of Levels I-IV</td>
</tr>
<tr>
<td>Population Study</td>
<td></td>
</tr>
<tr>
<td>Basic Science, Biomechanics, Validity Study, Professional Surveys</td>
<td></td>
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<tr>
<td>Reliability Study</td>
<td></td>
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</tbody>
</table>

Definitions of Methodological Terms22

1. Cost-Benefit & Cost-Effective Analysis: A form of economic assessment, usually from society's perspective, in which the costs of medical care are compared with the economic benefits of the care, with both costs and benefits expressed in units of currency or cost per unit of clinical effect. The benefits typically include reduction in future health care costs and increased earnings due to the improved health of those receiving the care.

2. Case Study (Single Subject Experimental Design): The intensive study of individuals through experimental designs such as the ABA, multiple baseline, and alternating treatment
3. **Case-Control Study (Case-Referent or Case-Comparison Study):** Study generally used to test possible causes of a disease or disorder, in which individuals who have a designated disorder are compared with individuals who do not with respect to previous current exposure to a putative causal factor. For example, persons with hepatic cancer (cases) are compared with persons without hepatic cancer (controls) and history of hepatitis B is determined for the 2 groups. A Case-Control Study is often referred to as a Retrospective Study (even if patients are recruited prospectively) because the logic of the design leads from effect to cause.

4. **Case Series:** A series of patients with a defined disorder. The term usually describes a study reporting on a consecutive collection of patients treated in a similar manner, without a concurrent control group. For example, a surgeon may describe the characteristics of and outcomes for 100 consecutive patients with cerebral ischemia who received a revascularization procedure. See also Consecutive Sample.

5. **Cohort:** A group of persons with a common characteristic or set of characteristics. Typically, the group is followed for a specified period to determine the incidence of a disorder or complications of an established disorder (ie, prognosis), as in Cohort Study (prospective study). See also Inception Cohort.

6. **Inception Cohort:** A designated group of persons assembled at a common time early in the development of a specific clinical disorder (eg, at first exposure to the putative cause or at initial diagnosis), who are followed thereafter. See also Cohort.

7. **Cohort Analytic Study:** Prospective investigation of the factors that may cause a disorder by comparing a cohort of individuals who do not have evidence of an outcome of interest but who are exposed to the putative cause with a concurrent cohort who are also free of the outcome but not exposed to the putative cause. Both cohorts are then followed to compare the incidence of the outcome of interest.

8. **Crossover Trial:** A method of comparing 2 or more treatments or interventions in which subjects or patients, on completion of the course of a treatment, are switched to another. Typically, allocation to the first treatment is by random process. Participants' performance in a period is used to judge their performance in others, usually reducing variability. See also Before-After Trial.

9. **Nonrandomized Control Trial:** Experiment in which assignment of patients to the intervention groups is at the convenience of the investigator or according to a preset plan that does not conform to the definition of random. See also Randomized Trial.

10. **Randomized Trial (Randomized Control Trial, Randomized Clinical Trial):** Experiment in which individuals are randomly allocated to receive or not receive an experimental preventive, therapeutic, or diagnostic procedure and then followed to determine the effect.
787 References
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II) Chiropractic Guideline for Spine Radiography for the Assessment of Spinal Subluxation in Children and Adults

RECOMMENDATION
Radiography is indicated for the qualitative and quantitative assessment of the biomechanical components of vertebral subluxation. When using radiography, a baseline value for subluxation displacement should be determined prior to the initiation of and at the cessation of a program of chiropractic treatment interventions. In this manner, patient response to care can be accurately determined.

Supporting Evidence: For all radiographic views combined (not separated out as in Section X): Clinical Levels I-V, Biomechanics, Reliability Class 1 and 2, and Validity.

A. Introduction to General Radiography
Radiography is a proven procedure for visualizing human anatomy and in particular spinal structures. The goal of radiography in chiropractic is to:

1. Make an assessment of spinal subluxation;
2. Make a determination of spinal health including the presence of any soft tissue injury, presence of any fractures, and the presence of any bony pathologies;
3. Make an assessment of any spinal instabilities;
4. Make an assessment any disc and other degenerative changes;
5. Make an accurate count of vertebra and levels for an individual patient.

Historically, Palmer termed the use of radiography in chiropractic to assess the spine as ‘Spinography’. The term Spinography provides for a Chiropractic focus and is defined as:

*Spinography is the chiropractic art of analyzing x-rays for the following purposes:*

1. Finding potential subluxations.
2. Understanding the anatomy to give the most appropriate adjustment.
3. Developing the most appropriate plan of care for the patient.

In the current PCCRP guidelines, we will use the term ‘Spinography’ and spinal radiography/x-ray analysis by the Doctor of Chiropractic interchangeably; the intended meaning is as defined by Palmer. Since the Doctor of Chiropractic has studied courses in x-ray physics, radiographic positioning, radiographic safety, radiographic diagnosis, and radiographic geometric line drawing analysis, he/she is expected to have a license to practice that is controlled by a government agency (State and Provincial Chiropractic Boards). As such, the chiropractic practitioner is expected to adhere to the local laws pertaining to x-ray equipment, x-ray safety, and all other such items that are concomitant with x-ray privileges granted by a government.

Some specific items of importance for the Chiropractic practitioner are listed here. These items include:

1. Principles of radiation protection, including shielding of various body parts, lead aprons, etc,
2. Proper screens and cassettes,
3. Proper film identification (patient name, age, date, clinic),
4. Proper identification of direction (left, right, oblique, etc),
5. Best visualization with a minimal exposure,
6. Appropriate Collimation,
7. Appropriate technique charts with exposure factors,
8. Radiographs should be reviewed before a patient is released for that day to insure that positioning and film quality is at an optimum.

B. Indications for Spine Radiography in Children and Adults

The main focus of this document is the following list of patient conditions that warrant a radiographic evaluation for the assessment of spinal subluxation. This evaluation for the assessment is independent of any “Red Flags” assessment. For the assessment of spinal subluxations, the Chiropractor becomes aware of conditions which affect the safety and appropriateness of chiropractic care by conducting a consultation that should include a personal history, family history, present complaints, and any recent or past traumas. Additionally, an orthopedic, neurological, range of motion (ROM), and a postural examination may be helpful.

Indications for spine radiographic examinations include, but are not limited to:

1. Abnormal posture,
2. Spinal Subluxation (as defined in this document),
3. Spinal deformity (eg, scoliosis, hyper-kyphosis, hypo-kyphosis, etc...),
4. Trauma, especially trauma to the spine,
5. Birth Trauma (eg, forceps, vacuum extraction, cesarean section etc...),
6. Restricted or abnormal motion,
7. Abnormal gait,
8. Axial pain,
9. Radiating pain (eg, upper extremity, intercostal, lower extremity),
10. Headache,
11. Suspected short leg,
12. Suspected spinal instability,
13. Follow-up for previous deformity, previous abnormal posture, previous spinal subluxation/displacement, previous spinal instability,
14. Suspected osteoporosis,
15. Facial pain,
16. Systemic health problems (eg, skin diseases, asthma, auto-immune diseases, organ dysfunction),
17. Neurological conditions,
18. Delayed developmental conditions,
19. Eye and vision problems other than corrective lenses,
20. Hearing disorders (eg, vertigo, tinnitus, etc...),
21. Spasm, inflammation, or tenderness,
22. Suspected abnormal pelvic morphology,
23. Post surgical evaluation,
24. Suspected spinal degeneration/arthritis,
25. Suspected congenital anomaly,
26. Pain upon spinal movement,
27. Any “Red Flag Conditions” covered in previous guidelines.
C. Spine Radiographic Examination

Since the spine is a contiguous structure that is inseparable in function it should be inseparable in an evaluation using Spinography. A radiographic examination of the spine may include an AP evaluation and a lateral evaluation of the entire spine. Additional views may be indicated in cases involving trauma. It is of some historical interest that the recommendations of Hildebrandt in 1985 are repeated here. In his classic 1985 text Chiropractic Spinography, Hildebrandt suggested that there are five projections that comprise a complete full spine analysis:

1. AP full spine
2. Lateral full spine
3. Femoral head view
4. Sacral base view
5. Upper cervical view.

For children younger than 10 years old, some of the five projections may not be needed, and the Chiropractor may use clinical judgment to determine which views are needed. If we pause to understand the reasoning behind Hildebrandt’s suggested five views for a complete spine evaluation, we may be able to elaborate on his suggestions.

First, the lateral full spine view will provide an analysis of several possible spinal subluxations:

1. a global view of the sagittal balance of C1, T1, T12, and S1,
2. an evaluation of forward/backward head posture,
3. an evaluation of forward/backward ribcage posture,
4. an evaluation of sagittal posture (from the postural examination) and spinal coupling on the radiograph,
5. an evaluation of cervical lordosis,
6. an evaluation of thoracic kyphosis,
7. an evaluation of lumbar lordosis,
8. an evaluation of pelvic morphology,
9. an evaluation of any retro- or spondylo-listhesis and,
10. an evaluation of spinal degeneration (vertebrae, discs, spinal ligaments).

If the Chiropractor does not have a full spine bucky and cassettes to obtain a full spine lateral x-ray, then three sectional views may substitute for this view. These sectional views are: lateral cervical, lateral thoracic, and lateral lumbo-pelvis.

Second, the AP full spine view will provide an analysis of several possible spinal subluxations including:

1. a global view of the AP balance of C1, T1, T12, S1,
2. an evaluation of segmental subluxations in the cervical, thoracic, and lumbar regions,
3. an evaluation of posture (knowledge from the postural examination) and spinal coupling on the AP radiograph,
4. an evaluation of any cervical scoliosis,
5. an evaluation of any thoracic scoliosis,
6. an evaluation of any lumbar scoliosis, and
7. an evaluation of pelvic and leg length asymmetry.
If the Chiropractor does not have a full spine bucky and cassettes to obtain a full spine AP x-ray, then three sectional views may substitute for this view. These sectional views are: AP cervical, AP thoracic, and AP lumbo-pelvis.

While the items listed above for the AP full spine and lateral full spine analysis may seem straightforward, one might ask why Hildebrandt suggested the femur head view, the sacral base view, and the upper cervical view (Nasium). To change from the fetal C-shape curve, the cervical vertebrae extend and the lumbar vertebrae extend. This extension to eventually assume an upright stance is restricted to the median-sagittal plane. Thus, while the spinal structures in the sagittal view are normally aligned perpendicular to the central ray, this extension of the spine to allow upright stance creates a situation where the AP x-ray beam is at an angle to the plane of the lower lumbar segments (L4-L5-S1) and upper cervical segments (C0-C1-C2) in the AP view. Additionally, any pelvic axial rotation in front of the grid cabinet will project one femur head lower than its twin on the other side. Thus, taken together the femur head view, the sacral base view, and the upper cervical view (Nasium) allow for assessment of the following subluxation types:

1. short leg causing an un-level sacral base and spinal AP curvatures on the short leg view,
2. an evaluation of the SI joints, sacral ala, L5, and L4, and lumbo-sacral angle at the sacral base on the Ferguson projection,
3. an evaluation of the skull-atlas and atlas-cervical spine as upper angle (UA), lower angle (LA), C2 axial rotation, and cervico-dorsal (CD) angle at mid neck on the AP nasium upper cervical view.

It can be argued that patients expect and deserve a thorough radiographic evaluation of their spines when any of the above indications are present. By following this radiographic set of views or subsets of, the majority of structural spinal subluxations can be located and measured. However, there are additional radiographic views needed to perform a thorough investigation in trauma and ‘deformity’ cases. These may include all or part of the following list:

1. Davis Cervical Series:
   a. AP cervical,
   b. Lateral cervical,
   c. AP Open Mouth (APOM),
   d. Flexion,
   e. Extension,
   f. Left oblique,
   g. Right oblique,
2. Weighted (sand bag) stress views in cervical lateral bending (alar ligament views),
3. Cervical Motion X-ray during flexion-extension, open-mouth lateral bending, and oblique lateral bending cervical articular facet views,
4. Lumbar flexion-extension,
5. Lumbar oblique,
6. Lumbo-sacral spot views, etc…,
7. Bending and/or postural stress films for flexibility assessment of scoliosis or buckling displacements (see Section V for definitions).
Historical Consistency

Again, it is of historical significance that the above recommendations are consistent with earlier recommendations. For example, in 1964 Jackson discussed that an adequate radiographic examination of the cervical spine is essential for patient diagnosis. She made an argument for the following radiographic views to be made routinely: an antero-posterior view of the upper two vertebrae, an antero-posterior view of the lower five vertebrae, an antero-posterior caudad-angled view to show the posterior structures of the vertebrae, three lateral views (neutral, flexion, extension) made with the patient in the upright position, and right and left oblique views.

D. Follow-up (post-evaluation) Spine Radiographic Examinations

Chiropractors attempting the assessment and correction of spinal subluxations need feedback as to the structural efficacy of their adjustment and spinal rehabilitative forces. If the chiropractor employs radiographic mensuration procedures for biomechanical assessment upon initial examination, follow-up (post) radiographs are appropriate for evaluating patient progress throughout a course of care.

Chiropractors interested in assessing subluxations and correcting subluxations are attempting to create improvement in spinal alignments with their treatment interventions; as such, the structural improvements measured via radiography are of concern. Analogous to this interest in structural assessment by chiropractic clinicians, is the same interest by orthopedic surgeons. It may be helpful to review the suggested frequency of follow-up radiographs (post treatment views) utilized by Orthopedic surgeons. Orthopedic surgeons often take initial pre-operative radiographs, immediate post-operative, one month, 6-12 months, and long-term follow-up radiographs (total of 5 sets of x-rays) for surgery cases. In fact, according to Fischgrund (2005, pp 1017 and 1023), "Routine cervical spine radiographs taken for the evaluation of degenerative disc disease and cervical radiculopathy include lateral, anteroposterior, and oblique views." Following surgical intervention, they state, "Typical follow-up of these patients includes an office visit at 1 week, with routine anteroposterior and lateral radiographs. By 6 weeks, lateral flexion and extension views usually show that the fusion construct is stable..." Fischgrund further stated that follow-ups are ascertained at 1 year, 2 years, or 5 or more years depending upon the specific study. Therefore, according to Fischgrund, surgery patients receive initial, 1-week post op, 6-week post op, and 1, 2, or 5 year follow ups.

In light of the above information it is the consensus of the PCCRP panel that indications for follow-up (post) radiographs are:

1. Post radiographs are indicated after a specific corrective adjustment to the upper cervical spine where the exact position of the CO-C1-C2 spine needs to be ascertained.
2. Post radiographs are indicated after the placement of an orthotic for the reduction of leg length inequality or sacral base un-leveling in the coronal plane.
3. Post radiographs are indicated after each 2 or 3 month time period of care using structural rehabilitative chiropractic treatment procedures.
4. Post radiographs may be indicated in a situation where the patient suddenly has an exacerbation during treatment.
5. Post radiographs may be indicated after significant trauma during a course of treatment.
6. Post radiographs are suggested at 6 months follow-up, 1 year, and 2 years.
7. For spinal instability, post spinal surgical cases, and recent spinal fracture cases, post radiographs may need to be taken at an increased frequency. 

**Early and Late X-rays of a Patient Following Sustained Trauma**

Post-traumatic progressive cervical ligamentous instability and spinal deformity may occur in spite of initial apparently normal spine radiographs. Patients at risk for the development of this problem are generally under the age of 25 and have >1.5mm of horizontal displacement and >5° of angular displacement on initial cervical x-rays.

**E. Position on Computerized analysis of radiographs.**

Recent advances in computer and radiographic technology has made it possible to both ascertain and analyze spinal x-rays with computer assisted methodology. It is becoming increasingly common for spinal health care providers, such as chiropractors, to use computer assisted methods to analyze spinal displacements. These computer methods are at least as reliable and valid as traditional ‘by hand’ radiographic analytical techniques. The current PCCRP guideline panel considers computer assisted radiographic analysis to be a reliable and valid procedure for spine analysis.

**F. Position on Videoflouroscopy or Digital Motion X-ray Analysis**

Videoflouroscopy can demonstrate different motion patterns between normal and pathologic spines. Cineradiography adds another diagnostic method of evaluating suspected soft –tissue injuries of the cervical spine by demonstrating motion during active exercise. It is reasonable to anticipate that abnormal motion will accelerate degenerative changes in the spine and will complicate the cineradiographic analysis. The cineradiographic study will have its greatest value in patients who show normal spines on standard roentgenograms and before degenerative changes have occurred. The incidence of apophysial joint abnormalities detected by cineradiography is higher than by plain roentgenograms. The cineradiographic study is of benefit in demonstrating either excessive or decreased mobility. It has proved of value in localizing the areas of abnormalities which correlate well with symptoms.

**Summary**

The PCCRP Guidelines developed and put forth above are evidence based recommendations for radiographic analysis of the spine for chiropractors in clinical practice. These PCCRP guidelines are consistent with previous historical works in the chiropractic literature. The remainder of this document provides the scientific rationale, evidence, reliability, validity, and clinical utility of the current PCCRP Guideline for Spine Radiography for the Assessment of Spinal Subluxation in Children and Adults.
References


III) Spinal Radiography Background, Utilization, and Costs

RECOMMENDATION

Spinal radiography is an important legal privilege of practicing chiropractors in North America, is an important component of chiropractors’ analysis and management of presenting patients, and should not be limited to the ‘red flag’ x-ray only model. The PCCRP guideline panel recommends against the exclusive adoption of ‘red flag’ guidelines as these do not benefit the individual patient, ignore vital difference in chiropractic treatment procedures versus standard medical or physical therapy treatments, and ignore a large body of contrary information suggesting spine radiography has clinical utility and validity relating to a variety of presenting conditions. The PCCRP panel recommends the guidelines for spinal radiography in chiropractic practice set forth in Section II.


PCCRP Evidence Grade: Clinical Studies = B and Basic Science, Biomechanics, and Validity Studies = a.

Introduction

Because of the early use of spinography in Chiropractic in the United States after 1910, there subsequently occurred laws in various English speaking countries giving Chiropractors radiographic privileges. These privileges are not available in many countries; in no small part due to the medical profession’s monopoly on such privileges. For examples, some Chiropractors in Europe, China, Korea, and Japan do not have x-ray privileges.

Countries in which Chiropractors have radiographic privileges include the United States, Canada, Great Britain, Ireland, Australia, and New Zealand. Because Chiropractic Colleges in these countries teach x-ray physics, x-ray safety, x-ray positioning, x-ray diagnosis, and x-ray line drawing analysis, these privileges are secured by State, Provincial, and Commonwealth law. However, there is a direct attack on Chiropractic radiographic privileges that does not come from outside our profession, but rather from within.1-26

For at least the past 20 years, a subgroup of the Diplomates of American Board of Chiropractic Roentgenology (DACBRs) and a few chiropractic academics have attempted to reduce x-ray privileges for practicing Chiropractic Clinicians. These suggested reductions in x-ray privileges by the subgroup of DACBRs and academics have come in the form of “expert opinion” chapters in various chiropractic texts,1-5 articles published in Index Medicus journals (JMPT, Chiropractic & Osteopathy),6-19 CINAHL and Mantis Indexes (Topics in Clinical Chiropractic, Chiropractic Technique, Journal of Chiropractic Medicine, and the Journal of the Canadian Chiropractic Association).20-26

Relying on selective literature citations and Clinical Class V (expert opinion) evidence instead of the available data, this subgroup of DACBR and academic “expert opinions” have claimed a series of positions that have been shown to be false.27-33 These include:

- Normal spinal position does not exist,
- Acute muscle spasms cause cervical and lumbar kyphosis or hypo-lordosis,
- Normal spinal anatomic variants cause the spine to appear to be subluxated,
- X-rays should not be taken for biomechanical, screening, and follow-up treatment x-rays are not warranted,
- Radiographic line analysis of spinal displacements is unreliable,
• X-ray positioning of patients is unreliable,
• X-ray analysis lacks predictive validity and biologic plausibility,
• X-ray use to dictate treatment does not yield improved patient outcomes,
• Most patient episodes of spinal pain are self-limiting and improve with time.1-26

Recently, this same subgroup of DACBRs and academics have been suggesting that Chiropractic x-ray privileges be confined to “Red Flag” cases only.1-5,8,9,21,26 Problematically, managed care organizations (MCO’s) use these “Red Flag” documents to enforce their mandatory reduction in radiographic utilization rates of practicing chiropractic clinicians.34,35 In fact, there is no evidence that these policies actually benefit the patient; but there is evidence that this increases the profits of MCO’s and insurance providers.36,37 Thus, it becomes clear that current attempts to limit radiography utilization rates of chiropractic clinicians is motivated more by profits and less by what is best for the patient.

Are Red Flag Guidelines Supported by Previous Studies?
There are some reports in the scientific literature that seem consistent with the above ‘Red Flag’ x-ray recommendation promulgated by the subgroup of DACBR’s.38-43 However, a review of these documents reveals several interesting issues. For examples:

1. In studies38,39 of patients involved in a variety of cervical spine trauma scenarios 2.4-2.8% reveal a ‘significant finding’.38 However, ‘significant finding’ is defined as cervical spine fracture. Whereas 17% of the cases are positive considering subluxation (instability), spondylo-listhesis, straightening, spasm, foreign body, compression, fusion, narrowing, or soft tissue swelling.39 It should be apparent that Chiropractors applying mechanical forces to cervical spines would benefit from being aware of these ‘other’ (17%) positive radiographic findings as treatment intervention can be altered.

2. In a randomized trial comparing the intervention of lumbar radiography to no radiography in patients with at least 6 weeks duration of low back pain, Kendrick et al41,42 found no differences in outcomes between the groups. Problematically, the intervention used for treatment did not specifically address any structural spinal displacements. In other words general medication, physical therapy, and other recommendations were utilized. Importantly, patients receiving radiography were more satisfied with the care they received.41,42

3. Patients whom are allocated to a preference group where the decision to receive lumbar radiography is made by them, achieve clinically significant improved outcomes compared to those randomized to a non-radiography or a radiography group.42 Thus, undercutting patient choice by ‘Red Flag’ only guidelines for chiropractic radiography limits the patients right to choose and can impair or slow recovery.

4. It is clear from these studies that the main justification to reduce the use of radiography is based on the argument of reducing physician ‘work load’ and reducing health care costs driven primarily by MCO’s and 3rd party payors.40-43

Contradictory Studies to ‘Red Flag’ Only X-ray Guidelines
There are a multitude of studies that demonstrate strong correlations in radiographic measured spinal alignment variables in spinal disorders between a ‘condition group’ and a control group without the condition.44-64,117 These studies demonstrate the validity and usefulness
of spinal radiography in determining alignment abnormalities that predict, correlate to, predispose to, and/or complicate a variety of spinal and health disorders. While section X provides a comprehensive review of studies supporting the validity and utility of spine radiography under each individual radiographic view, we present a review of twenty two key studies here for completeness:

**Lumbar spine**

1. In a review of four hundred and sixty-four age-matched (mean age 18 years 6±2 months) consecutive male army recruits, Steinberg et al found that half had a history of episodes of low back pain (LBP). Several associations between different radiographic findings and low back pain (LBP) were found among the recruits with LBP including: 1) an increased frequency of right-sided scoliosis, 2) lumbar lordosis, 3) sacral lumbarization, 4) wedge vertebra, 5) bilateral spondylolysis of L5 and/or a sagittal diameter of less than 12 mm.

2. In a prospective cross-sectional study Inaoka et al compared the lumbar radiographic findings of 438 subjects with chronic LBP or lower extremity pains to 400 age, sex, height, and weight matched controls. Patients with LBP showed a significantly high incidence of intervertebral space narrowing, irregular ossification of end-plate image, spondylo-listhesis, and abnormal reduced lumbar lordotic angle. They concluded that when a patient presents with more than one of these associated factors, the incidence of LBP increases significantly.

3. In a prospective study of 253 chronic LBP patients matched by age and physical characteristics to 253 normal controls between the ages of 50-85 years, Tsuji et al found a reduced L1-S1 lordosis in the chronic LBP group. Of primary importance, lumbar lordosis was inversely correlated with pain intensity on a visual analog scale (p= 0.025). In other words, as the lumbar lordosis decreased, the pain intensity of the subject was increased.

4. Tsuji et al prospectively evaluated 25 patients with chronic patellar femoral pain (CPFP) and matched them to 60 normal control subjects. They excluded subjects with spondylo-listhesis, fractures, and surgery. Using the L1-S1 4-line Cobb angle, lumbar lordosis and sacral inclination were found to be statistically decreased in patients with chronic LBP and CPFP. Tsuji et al concluded that reduced lordosis and sacral tilt caused increased thigh muscle strains, knee flexion, and eventual CPFP and LBP.

5. Jackson and McManus reported one of the first investigations to measure all segmental angles as well as total curve angle in a prospective sample of 100 normal controls matched to 100 Chronic LBP patients. Total lordosis was significantly less in chronic LBP patients and was not age or sex related. Importantly, Patients with LBP tended to stand with less distal segmental lordosis, but more proximal lordosis, and reduced sacral inclination.

6. Harrison and colleagues compared the lumbar lordotic alignment of 50 normal controls matched to 50 chronic LBP patients, 50 acute LBP patients and 24 subjects with LBP and lumbar degenerative disorders with no history of pain, treatment, anomalies or DJD. This
sophisticated study found differences in segmental and endpoint measures of lumbar lordosis as well as different geometrical elliptical models between these four groups. Specifically, the chronic LBP subjects had reduced lumbar lordosis, acute pain subjects had hyperlordosis, and the degenerative disorders group had reduced lumbar lordosis and ellipses could not fit these subjects’ spinal geometry.

7. Korovesis et al\textsuperscript{50} prospectively evaluated the lumbar lordosis in 100 normal controls age, sex, weight, and occupation matched to 100 Chronic LBP subjects between the ages of 20-70 years. In addition, to radiographic alignment, all subjects completed the short form 36 questionnaire. It was found that chronic LBP statistically correlated to general health, physical function, emotional function, social function and pain. Importantly, all these variables were statistically correlated to a reduced overall lumbar lordosis, a reduced L4-S1 lordosis, and a reduced L4-S1 disc height index. They concluded, “There seems to exist a link between sagittal lumbar spine radiology and subjective assessment data (SF-36) in a homogenous hardworking male population with LBP”.\textsuperscript{50}

8. In a 1-year prospective study, Reigo et al\textsuperscript{51} followed 207 women and 176 men between the ages of 20-59 years of age in order to see if physical characteristics could predict new episodes of low back pain and sick leave. New sick leave, long-term sick leave, and lower back pain were correlated to a flattened lumbar lordosis, tenderness in the trapezius muscle, and decreased cervical ROM.

9. In a study of 110 cases of acute low back pain, Reinert\textsuperscript{52} identified the frequency of occurrence of intervertebral disc-space wedging, the level where it most frequently occurred and the associated alterations in the attitude of the pelvis and adjacent vertebral segments. Correlation of the location of pain with the distorted structural positions was significant. Thus spinal subluxations were correlated to acute uncomplicated low back pain.

Lateral Full Spine

10. Glassman et al\textsuperscript{53} assessed 752 patients with adult spinal deformity using the lateral full spine x-ray and the SRS patient questionnaire, MOS short form-12 questionnaire, and the Oswestry Disability Index. On x-ray, 352 patients were found to have anterior sagittal translation of the C7-S1 plumb line with a range from 1mm-271mm. All measures of health status showed significantly poorer scores as the C7 plumb line deviation increased. Patients with relative kyphosis in the lumbar region had significantly more disability than patients with normal or lordotic lumbar sagittal Cobb measures.

11. Kobayashi and colleagues\textsuperscript{117} prospectively followed 100 subjects aged 61.9 yrs for a mean of 12 years. Full spine radiographs were ascertained at initial and long-term follow up in an attempt to identify if sagittal plane radiographic alignment variables play a role in the risk for developing new vertebral compression fractures. In both univariate and multivariate analysis, reductions in lumbar lordosis (Cobb L1-L5) and thoracic kyphosis (Cobb T4-T12) increased the relative risk of developing a new vertebral body compression fracture. Significantly, even curves one standard deviation below the mean value showed statistically significant increased relative risks (RR 3.06). Their\textsuperscript{117} most
statistically significant model was multi-variate including pre-existing compression
fractures with both the lumbar lordosis and thoracic kyphosis decreased (RR 8.64).
Kobayashi and colleagues\textsuperscript{117} suggested that flattened curves reduce the shock absorbing
capability of the sagittal curves, increasing the dynamic loads on the vertebral bodies thus
increasing the risk of fractures.

**Lateral Thoracic**

12. Kolessar\textsuperscript{54} evaluated 69 patients with Scheuermann’s or postural kyphosis matched to 43
asymptomatic controls. On the lateral thoracic x-ray, the Cobb angle from T5-T12, was
54° in the Scheuermann’s kyphosis group, 48° in the Postural kyphosis group, and 32° in
the controls. They\textsuperscript{53} state, “Most authors would agree that the upper limit of normal for a
Cobb measurement (ends) should not exceed 45°.” and “We recommend additional
lateral radiographs to visualize the proximal thoracic spine in patients with a
measurement from T5-T12> 33°” A Cobb angle of 33° from T5-T12 had a specificity of
56% for discrimination between subjects.\textsuperscript{54}

13. Lind et al\textsuperscript{55} investigated the correlation between hyperkyphosis and uterine prolapse in
48 cases of uterine prolapse to past the introitus compared to 48 controls matched by age, weight, menopausal status, and hormonal status. On lateral thoracic x-rays, kyphosis was
measured with the Fergusson Method and measured 13° in the prolapse groups and 8.1°
in controls. The group differences were statistically different (p<0.001) and for each 1°
increase in kyphosis, the risk of uterine prolapse increased by 1.35 times.

**Lateral Cervical**

14. In a 1-year prospective study of 110 patients with neurogenic thoracic outlet syndrome
(NTOS) as a consequence of whiplash injury, Kai et al\textsuperscript{56} found a prevalence of cervical
kyphosis of 44%-46% in the patients with NTOS vs. only 11-24% in subjects without
NTOS. Kai et al\textsuperscript{56} concluded that reversal of the cervical lordosis is abnormal and
associated with future disability after whiplash.

15. In an investigation of 100 patients with sub acute whiplash associated disorders (WAD),
Giuliano et al\textsuperscript{57} found a prevalence of 98% for loss of the cervical lordosis compared to
only 4% in 100 matched normal controls. The cervical lordosis was measured via MR
imaging.

16. In 372 patients with tension headaches matched to 225 controls for age and sex,
Nagasawa et al\textsuperscript{58} found a statically reduced cervical lordosis on x-ray. The cervical curve
was measured using Ishihara’s Index. With increasing age, the patients with headaches
had a cervical curve that was straight with increased frequency.

17. In 277 subjects with and without cervico-genic pains presenting to a chiropractic clinic,
McAviney et al\textsuperscript{59} found that patients with a lordosis of 20° or less were more likely to
suffer from cervicogenic symptoms (p<0.001). The association between cervical pain and
lordosis ≤ 0° was highly significant (p<0.0001). The odds that a patient with cervical
pain had a lordosis ≤ 0° was 18 times greater than for a patient with a non-cervical
complaint. Patients with cervical pain had less lordosis and this was consistent over all
age ranges. Receiver operating characteristic curves were analyzed and lordosis less than 20° had good sensitivity and specificity for identifying those with and without cervical pain.

18. In a modeling study, Harrison et al\textsuperscript{60} evaluated the predictive validity of their circular model to discriminate between normal subjects and those with chronic and acute cervical spine pain disorders. Both radiographic measurements and circular modeling variables were found to have good sensitivity and specificity for group cutoff values. Chronic pain subjects had a lordotic value of 20° or less, acute pain subjects had a lordotic value of less than 30°, and normal subjects had a lordosis greater than 30°.

19. Jochumsen\textsuperscript{61} classified the lateral cervical x-rays of 500 patients into 6 different geometric categories. In 100 of these cases, subjects were asymptomatic and 400 cases presented with cervico-genic symptoms. He found that “patients with a straightened curve are more disposed for cervical symptoms than patients with a mean lordosis or hyperlordosis”\textsuperscript{60}.

20. Ng\textsuperscript{62} compared the upper cervical misalignments of 10 patients with headaches to 13 asymptomatic controls. The C1 laterality (UA) on the nasium demonstrated significant differences being 3.1° in patients and 2.0° in controls.\textsuperscript{61}

21. In a retrospective examination of 335 AP cervical radiographs of patients screened for lateral head translations ≥5mm, Oakley and Harrison\textsuperscript{63} identified 176 (53%) patients with this AP cervical subluxation. Of these 176 patients, 146 patients (67 male; 79 female) had head/neck complaints. Thirty-eight percent of neck pain patients (56/146) had left head shifts while 62% (90/146) had right head shifts. Those with left head shifts suffered from pain longer but had smaller absolute mid-neck angles. Significant correlations existed between patient age and pain duration, pain duration and head translation distance, absolute head translation distance and age and absolute mid neck-angle and neck disability index (NDI) score.\textsuperscript{63}

22. In a study by Friberg\textsuperscript{64}, where 288 chronic low back pain subjects were matched to 366 asymptomatic controls, the incidence of leg length inequality (LLI) was significantly higher in the pain subjects compared to asymptomatic controls. The magnitude of the LLI difference was more than double (10.6 mm vs. 5.1 mm) in the pain group compared to the controls.

Discussion

In opposition to the current PCCRP Guideline’s views, proponents of the ‘red flag’ only x-ray position, claim that: “There is no convincing evidence that use of radiography for spinal biomechanical assessment (other than for assessing scoliosis) is of any therapeutic value”\textsuperscript{26} and no RCTs have been performed demonstrating the superiority of conservative (non-surgical) techniques utilizing x-ray for treatment decision making.\textsuperscript{25,26} In rebuttal, both of these opposition
statements are false. The twenty two studies presented above\textsuperscript{44-64,117} clearly demonstrates the validity of radiographic analysis of spinal misalignment.

Second, there are preliminary RCTs using the AP Nasium and AP Fergusson/pelvic views that demonstrate improved patient outcomes by addressing and correcting the structural component of spinal subluxation/displacement.\textsuperscript{65,66,143}

Third, sole reliance on the evidence from RCTs, while ignoring the other categories of evidence described in Section I, is professionally and scientifically unrealistic. Smith and Pell\textsuperscript{67} presented a timely systematic review of RCTs on the use of parachutes to prevent death and major trauma in order to chastise those in the scientific community who ignore evidence Levels II-IV when no RCTs exist. They found no RCTs demonstrating that use of a parachute can prevent serious injury or death. Smith and Pell\textsuperscript{67} concluded that \textit{“Individuals who insist that all interventions need to be validated by a randomized controlled trial need to come down to earth with a bump,”} and volunteer for the control group in a double blind, randomized, placebo controlled, crossover trial of the effect of parachute use. In other words, Smith and Pell\textsuperscript{67} were arguing for the use of common sense and consideration of all types of evidence in implementation of ‘evidence based medicine’; the PCCR panel concurs.

\textbf{Degenerative Joint Disease (DJD), Spine Pain and Health Disorders}

There exists an opinion in the spinal health literature that the presence and extent of spinal degenerative joint disease is unrelated to back pain conditions and patient health.\textsuperscript{119}

In truth, there are both positive and negative study findings regarding the correlation between spinal pain and spinal degeneration; but the number and quality of studies is weighted on the positive side (there is a correlation). There are several positive long-term follow-up studies,\textsuperscript{120-123} health outcomes,\textsuperscript{124} nerve function,\textsuperscript{125} and biomechanics\textsuperscript{126-130} showing a correlation between pain, function, health and mild-moderate DJD. There are also, cross-sectional prospective studies.\textsuperscript{131-133}

\textbf{Lumbar DJD}

For example, in a prospective study of 286 men and 299 women over the age of 50, Pye et al\textsuperscript{131} investigated the correlation of current and past low back pain with the radiographic presence and severity of anterior osteophytes, endplate sclerosis, and disc space narrowing from L1/2 to L4/5 levels. Subjects with disc space narrowing were more likely to report back pain both in the past and in the previous year (odds ratio (OR) = 1.7); the statistical significance of this correlation increased with increasing severity of narrowing. Further, moderate endplate sclerosis was associated with back pain in the past and in the previous year; similar findings were found for moderate sized osteophytes.\textsuperscript{131}

Likewise, O’Neil and colleagues\textsuperscript{132} prospectively evaluated 681 women and 499 Men aged 50 years. Lateral spine radiographs were evaluated by a single observer for the presence of osteophytes from T4 to L5 using a grading score from 0-4 (0 = none, 1 = doubtful, 2 = mild, 3 = moderate, 4 = severe). Increasing body mass index was associated with more frequent osteophytes for both the thoracic and lumbar regions. Heavy physical activity in subject’s youth was associated with the presence of osteophytes in men. Importantly, self-reported back pain, both “ever” and “in the past year”, was statistically correlated with lumbar osteophytes in males.\textsuperscript{132}
Critical to the understanding of spinal DJD and patient outcomes are biomechanical and neurophysiological alterations caused by DJD. In fact, the neurophysiological responses of the normal and degenerated ovine (sheep) spine, subjected to mechanical excitations consistent with spinal manipulative therapy (SMT), have been investigated. Using needle electromyographic (EMG) multifidus muscle activation and compound action potentials (CAP) of the L4 nerve roots, in the disc degeneration group a 20-25% reduction in positive EMG responses and a concomitant increase (4.5 to 10.2%) in CAP responses were found.

Additionally, recent studies have detailed the biomechanical consequences of intervertebral disc degeneration. In prospective cross-sectional and longitudinal studies on post-menopausal women, Sornay-Rendu et al identified that disc degeneration leads to a statistically significant increased risk of vertebral fractures that is independent of bone mineral density. This finding is likely due to the altered stress/strain relationships of the vertebra above the area of DJD.

Cervical DJD Pain and Health Disorders

In a minimum 10 year longitudinal study of 159 asymptomatic subjects, Gore found 15% of previously asymptomatic subjects developed neck pain and “...that the presence of degenerative changes at C6-C7 on the initial roentgenogram was a statistically significant predictor of pain” at the minimum 10 year follow-up exam. Peterson et al found a statistically significant positive correlation (described as weak but still significant) between self-reported pain intensity and the severity of disc DJD. Likewise, in a review of cervical spine radiographs of 5,440 men and women between 20 and 65 years of age, van der Donk et al found that “disc degeneration was associated with neck pain in the men but not in the women.” Norris and Watt followed 61 patients involved in motor vehicle accidents for an average of 2-years. The patients were categorized into three groups: 1) cervico-genic symptoms without positive physical exam findings, 2) symptoms with reduced cervical spine range of motion (ROM), and 3) symptoms with reduced ROM and neurologic deficits. Norris and Watt found “...pre-existing degenerative changes in the cervical spine, no matter how slight, do appear to affect the prognosis adversely.”

In a prospective, cross-sectional survey of 700 consecutive patients, Marchiori and Henderson investigated the correlation between cervical degenerative disc disorders and neck pain, disability and chronicity of pain. A significant relationship (p < 0.001) was found between the number of levels of intervertebral disc degeneration and the chronicity of cervical complaint. Multiple-regression analysis of neck disability index scores demonstrated a significant three-way interaction of chronicity, degeneration, and gender (p = 0.022).

Lastly, one investigation identified a correlation between abnormal/altered auditory evoked brainstem potentials and the presence of cervical spine DJD. This important study demonstrates that degeneration of the cervical spine is associated with ‘nerve interference’.

PCCRP Discussion

It is noted that moderate-severe radiographic determined spinal DJD can be a serious health disorder associated with a myriad of clinical conditions and that moderate to severe DJD always begins as mild DJD. In Chiropractic clinical practice, radiography is the only means of detecting a patient’s unique state of spinal health. We suggest that the prudent chiropractic clinician should do their best to control for specific risk factors linked to the development and
progression of spinal DJD. These risk factors can include: diet, smoking, body mass (obesity), physical activities, and *abnormal spinal and postural alignment*.\(^{120,124,132,133,140-142}\)

It is the PCCRP’s position that in Chiropractic clinical practice, the duty and responsibility of the clinician is to identify the spinal dysfunction via routine spinal radiography of the individual and develop solution strategies when and where possible. Because the scientific evidence indicates that spinal radiography is able to identify salient features (anomalies, pathologies, DJD) that correlate to a specific patient’s health disorder. The astute Chiropractor would understand that these features can alter and dictate treatment interventional strategies.

**Natural History of Low Back and Neck Pain**

A further contention against the ‘routine use of radiography’ by some chiropractic academics is the undertone that low back pain (LBP) and neck pain (especially acute pain episodes) are self limiting conditions that improve on their own over time. For example, Cooperstein et al\(^{25}\) stated, “…*pain levels tend to decline due to the passage of time.*” Several ‘evidence based guidelines’ maintain this position as well, especially for acute pain episodes.\(^{68}\) (See section VI for a detailed review of previous spine radiology guidelines).

**LBP Natural History:** One of the original articles to which the self limiting nature of LBP can be traced comes from Dixon\(^{69}\), where a “90% recovery” of acute LBP was found and was based on a record review in one general practice. However, the inference that a patient has completely recovered based on record review is clearly not supportable. In fact, there is **no** evidence supporting the claim that 80–90% of LBP patients become pain free within 1 month and strong evidence that refutes such claim.\(^{70-79,144-146}\)

Some investigations have identified that a minimum of 75% of patients with acute uncomplicated LBP will continue to have problems. At 3 and 12 months follow up, only 39/188 (21%) and 42/170 (25%) respectively will be recovered.\(^{71}\) In a 5 year follow up of 254 people (81% of the original sample) with non-specific low back and neck pain, Enthoven et al,\(^{72}\) reported that 52% of the sample reported ratable neck and low back pain and disability. Further, 63% of the 254 patients reported recurrence and/or constant pain.

In one of the longest follow up surveys to date, Kaaria et al\(^{79}\) reported on the initial, 5, 10, and 28 year low back pain prevalence and incidence in a population of Finnish metal workers. Initially, 54% of the cohort reported low back pain (LBP) and 25% reported radiation into the lower extremity (LEP). In the group with LBP, 75%, 73%, and 88% reported pain at 5, 10, and 28 year follow-up respectively. In the group with LEP, 66%, 65%, and 69% reported pain at 5, 10, and 28 year follow-up respectively. Kaaria et al reported odds ratios of 6.0 (LBP) and 8.5 (LEP) for the likelihood of those with LBP and LEP initially reporting the same pains at long-term follow-up. Thus, LBP and LEP are not self-limiting conditions that remit on their own over time; the initial presence of pain is a strong risk factor for future pain.\(^{79}\)

**NP Natural History:** Like the natural history of low back pain, the same general trend, that neck pain does not improve on its’ own, can be found for population based incidence and prevalence studies on neck pain.\(^{80-85}\) For example, in three separate clinical control trials on chronic neck pain populations, Harrison et al\(^{80-82}\) found that over an 8-9 month time interval, the numerical rating pain intensity score remained approximately the same at follow-up of control subjects receiving no treatment.
PCCRP Discussion

The available scientific literature detailing the natural history of spinal pain \(70-85\) contradicts the generalized Class V evidence by some Chiropractic academics.\(^{25,68}\) This information has great relevance to the topic of Chiropractic radiography. In fact, the current accepted model for acute and chronic spinal pain is that pain is not self-limiting; a large percentage of individuals will continue to have long lasting pain and/or periodic painful episodes.\(^{70-85}\)

There are identifiable physical exam findings and diagnostics that contribute to the poor natural history of spinal pain.\(^{70-75}\) Historical and current chiropractic philosophical and scientific tenets’ proclaim that spinal subluxation (See Section V for definitions) is a contributing cause to spinal pain episodes. The 21 studies presented above indicate that these chiropractic tenets have validity in specific populations of acute\(^{49,51,52,58,59}\) and chronic pain conditions.\(^{44-51,53-64}\)

Furthermore, chiropractic tenets proclaim that chiropractic is more than a musculoskeletal pain relief field. The majority of chiropractic clinicians do not want to be limited to ‘musculoskeletal pain relief’ and believe that spinal subluxations can cause and are correlated to a variety of health disorders;\(^{86}\) there is preliminary scientific evidence for this (See Section X). Therefore, the attempts to selectively limit chiropractic radiography to specific pain types and duration\(^{26,87}\) do not fit current chiropractic beliefs, practices (See Section IV), and are contradicted by good scientific evidence.\(^{44-64,70-85}\) (See section X for additional scientific support).

Chiropractic Needs Different Radiology Guidelines Due to Unique Analysis & Treatment

It has been suggested that guidelines for chiropractic clinicians’ utilization of x-ray should be different from those of a medical practitioner who does not use spinal adjustments and rehabilitation procedures as treatments to correct spinal subluxations.\(^{88,89}\)

There is an expectation by the consumer to have a thorough spinal evaluation when seeing a DC for a health problem. This expectation includes an x-ray evaluation for alignment of the spine and the state of health of the spine.\(^{90}\) While cost-effectiveness analysis may favor limited x-ray utilization in a volume 3rd party payer scenario where maximization of profits is the driving force, in the individual case, specific circumstances can lead to a different conclusion. In other words, in Chiropractic clinical practice, the needs of the one out weigh the needs of the many or the 3rd party payer. In chiropractic clinical practice, the duty and responsibility of the clinician is to identify the spinal problem of the individual and develop solution strategies when and where possible.

In studies specifically considering the role of chiropractic treatment interventions, spinal radiographic views indicate that between 66%-91% of patients can have significant abnormalities affecting treatment.\(^{91-93}\) 33% can have relative contraindications and 14% can have absolute contraindications to certain types of chiropractic adjustment procedures.\(^{91}\) Along this line, a review of 413 patient cases by Pryor and McCoy\(^{92}\) found a prevalence of 91% for anomalies and pathologies that might alter the chiropractic management of presenting patients. Similarly, in a review of 847 full spine patient radiographs, Beck et al\(^{93}\) identified anomalies and pathologies in 68% of patients; at least 6% of these were considered absolute contraindications to certain types of chiropractic treatments.

Information regarding anomalies and pathologies is especially important for Chiropractic clinicians performing structural corrective types of techniques aimed at altering the spine and posture. Potentially, this mandates an initial radiographic examination be performed. As stated
by Maigne,\textsuperscript{118} and shown in several Chiropractic Techniques, analysis and treatment interventions are modified when anomalies and pathologies are present in a specific patient’s spine.

Cost of Chiropractic Radiography

Over the past 25 years, there have been several publications comparing costs of Chiropractic care versus Medical care,\textsuperscript{94-108} but none have provided data on radiography. Most of these studies are comparisons for workers’ compensation injuries,\textsuperscript{94-100,102,107} while only a few are for general practice conditions.\textsuperscript{101,104,108} We will only briefly report on 4 recent publications.\textsuperscript{106-109}

In 1999, for radiographic interpretation of the lumbar spine and complete radiographic examination in an example adult female patient, Hess and Mootz\textsuperscript{106} compared Chiropractors to Orthopedists, Physical Medicine, Osteopaths, Neurologists, Rheumatologists, and Radiologists. The work (time involved) reported by DCs for obtaining, evaluating, and analyzing low back radiographs was higher than other specialties, but cost of services were not provided.

In a review of the literature in 2001, for occupational low back pain, Baldwin et al\textsuperscript{107} stated that, “the current literature suggests that chiropractors and physicians provide equally effective care for OLBP but that chiropractic patients are more satisfied with their care.” While radiographic costs were not directly mentioned, they stated that “Evidence on the relative costs of medical care and chiropractic care is conflicting.”\textsuperscript{107}

In 2005, Haas et al\textsuperscript{108} reported on approximately 2,800 self-referring patients, who sought the services of DCs and MDs in Washington and Oregon. They did not separate “Office Costs” into its components, and thus, no inferences about radiographic costs can be made.

In 2006, Bussieres et al\textsuperscript{109} wrote an article critical of radiation Hormesis, which was rebutted by Oakley et al.\textsuperscript{110} Bussieres et al\textsuperscript{109} claimed that there is “high health care costs associated with unnecessary diagnostic radiography” and cited six studies from MD practices and hospitals in the UK and Canada.\textsuperscript{111-116} This is a common error that critics of the use of radiography in chiropractic make, i.e., they cite medical studies for radiography utilization and then apply these studies to chiropractic practice. Radiography is of little use when your treatment is pharmacology (medication), advice, or generalized exercises. However, when the treatment is physical forces that are applied in manual therapy and chiropractic adjustments, radiography is a necessity for ruling out contraindicating pathologies to applying forces to the spine, accounting for anomalies that might alter physical forces applied, and for determining where spinal displacements are located in order to determine corrective physical forces.

In summary, while no direct evidence was located for costs of radiography in chiropractic practice, it seems obvious that chiropractors have relatively low costs of evaluation procedures and longer treatment care programs than Medical Doctors (MD’s). MDs are higher in costs in examinations and evaluations and lower on the costs of treatment, unless surgery is provided, in contrast to DCs. We suggest that radiography costs in chiropractic care are minimal.

Summary

A few chiropractic radiologists and chiropractic academics are attempting to restrict and/or limit the use of chiropractic radiography in clinical practice to ‘red flag’ situations only. This attempt to limit the ability of chiropractic clinicians to use radiography in their treatment decisions of patient care is primarily driven by a cost-reducing model of health care and supported by use of a limited number of investigations using entirely different analysis and
treatment regimens (standard pharmacology or physical therapy interventions) than those utilized by practicing chiropractors. Furthermore, these few chiropractic radiologists and academics utilize one sided literature presentations and Class V evidence (expert opinion) to claim spinal radiography has no place in spinal subluxation evaluation by chiropractic clinicians. The current PCCRP expert panel of chiropractic clinicians deems initial spine radiography to be clinically warranted to evaluate the spine for subluxation (defined in Section V), contraindications to treatment, treatment modifications, and treatment applications in general. The PCCRP Guidelines presented in Section II of this document fulfill the void in this arena and are the needed supporting evidence to show that attempts at reducing Chiropractic legal privileges in the radiographic arena are unfounded (see Section XIII).


IV. Historical & Current Perspective

RECOMMENDATION

Chiropractic radiography to assess spinal position is a procedure practiced by the majority of chiropractic clinicians in recent and past surveys; as such it can be considered an integral part of the standard of care in clinical evaluation of a presenting patient. The PCCRP Guidelines in Section II are recommended for Chiropractic clinical practice.

Supporting Evidence: Historical Literature Surveys, Professional Surveys, and Biomechanics Studies.

PCCRP Evidence Grade: Professional Surveys and Biomechancis Studies = a.

Introduction

Historically, radiographic spinal analysis has been an integral part of a Chiropractic evaluation. The use of x-ray for clinical decision making dates back to BJ Palmer in 1910. In the interval 1910-1950, many Chiropractic Techniques were originated that used x-ray to determine subluxation listings (PRS, PLI, body right, Upper Angle, Lower Angle, PIEX, etc). These include HIO, Wernsing’s Atlas Specific, Grostic, Gonstead, Diversified, Zimmerman’s Specific Adjusting, and Logan Basic.

After 1950, several new adjustable technique systems that utilized x-rays for clinical decisions were invented: Mears, Atlas Orthogonal, Life Cervical, Pettibon, CBP, Blair, Pierce-Stillwagon, Toftness, Barge’s Tortipelvis and Torticollis, Orthospinology, Stucky Integrated Methods, and NUCCA. Since 1947, Diversified has continued to be taught as a system which utilized a specific spinal listing obtained from x-ray analysis. Initial radiographs are a necessity in some of the chiropractic techniques practiced by the majority of chiropractors. This is evident by the National Board of Chiropractic Examiners’ surveys on utilization of techniques in the past few years. It is known from theses surveys that Gonstead, HIO, Logan Basic, and Pierce-Stillwagon are four of the most prevalent chiropractic techniques and radiographic analysis is a necessity in the majority of these techniques.

In a survey of 108 participating North American practices, Hawk et al (their Table 10, page 167) reported Chiropractic Biophysics (CBP®) technique to be the 8th most utilized technique in chiropractic practices. Of interest, CBP® recommends initial full spine radiographic evaluation of presenting patients be performed by chiropractic clinicians. Truth be known, a plethora of techniques taught in Chiropractic Colleges utilize initial radiographic analysis of presenting patients.

In national and international surveys specific to the topic of radiography utilization in chiropractic practice, it is found that Spinography is a primary assessment procedure utilized by more than 50% of the profession on at least 60% of their presenting patients.

However, in surveys specific to lower back pain, Chiropractors in North America utilize spinal radiography on their presenting patients at a frequency of 64%-95%. For example, in a survey of low back pain patients presenting to 32 urban and 32 rural Chiropractors, Carey and Garret found that 62% of the patients seen by chiropractors and 70% of those seen by orthopedic surgeons received spinal radiography. In another survey of 50% of Washington State Chiropractors (209 respondents) and 476 Family Physicians in active practice, Cherkin et al posed the utilization rate of lumbar x-rays for three hypothetical patients with increasing severity of low back pain and duration. Chiropractors reported a utilization rate of lumbo-sacral...
radiography from 92%-95% whereas Family Physicians reported that they would utilize 2149
radiography 10%-93% for the 3 cases. Of interest, 10-22% of the Chiropractors reported that 2150
they would order cervical spine and full spine radiography as well. Lastly, in a small sample of 2152
32 chiropractors from Ontario, Canada, Ammendolia et al 2149 reported that 63% of the 2153
Chiropractors in the intervention group and 54% in the control group requested lumbar 2154
radiography in ‘uncomplicated acute low back pain patients; 68% of the intervention and 64% of 2155
the control chiropractors believed radiography was useful in these cases.

The increased utilization rates of spinal radiography by Chiropractors, is likely a result of 2156
different philosophies, analysis, treatment approaches, and treatment outcomes inherent in 2158
Chiropractic. Because a majority of Chiropractors utilize radiographic analysis for 2159
biomechanical evaluation of the patient’s structural spinal position/abnormality (subluxation 2160
defined in Section V), the use of initial x-rays for biomechanical evaluation of the spine can be 2161
considered part of the standard of practice for clinical chiropractic. 12,20,40,43-49

Additionally, abnormal postural displacements of the head, thorax, and pelvis (main 2162
motions) are known to cause spinal displacement patterns (coupled motion), and thus, abnormal 2164
posture is a type of spinal subluxation (see Section V) and is reason enough to take routine x- 2165
rays on presenting patients for subluxation detection. The measurements gathered from the 2166
posture and x-rays of the spine are used by chiropractic clinicians to uniquely determine the 2167
specific interventions chosen for each individual patient. 1-11,13-19, 24-32,34-35,38

The ACA Technique Council meeting on March 13, 1992 identified the 15 Chiropractic 2168
Technique methods taught at Chiropractic colleges. These were/are Diversified, Gonstead, 2169
NUCCA, Grostic, CBP®, Logan Basic, Meric, Toggle-recoil, Cox, Thompson, Activator, SOT, 2170
AK, Nimmo, and Motion Palpation. It is noted that at least the first 9 of these techniques in this 2172
list utilize initial x-ray for either spinal diagnosis and/or decision on a subluxation listing.

In a summary of the various historical and current chiropractic identity groups, Keating41 2173
noted that all groups agreed that a primary method for spinal evaluation was spinal radiography. 2174
Keating’s 41 table 2-8 is reprinted here in an adapted form for this document; see Table 1.

<table>
<thead>
<tr>
<th>Chiropractor’s Role</th>
<th>Primary Spinal Evaluation Method</th>
<th>Professional Organization Advocates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary care physician</td>
<td>Radiography</td>
<td>American Chiropractic Association (ACA), Council on Chiropractic Education (CCE), ACA-Council on Diagnosis and Internal Disorders (CDID)</td>
</tr>
<tr>
<td>Musculoskeletal specialist</td>
<td>Radiography</td>
<td>ACA, CCE, American Council on Chiropractic Orthopedics (ACCO)</td>
</tr>
<tr>
<td>Chiropromedical specialist</td>
<td>Radiography</td>
<td>National Association of Chiropractic Medicine (NACM)</td>
</tr>
<tr>
<td>Radiologist or other diagnostician</td>
<td>Radiography</td>
<td>ACA, CCE, American College of Chiropractic Radiologists (ACCR)</td>
</tr>
<tr>
<td>Adjustor 1</td>
<td>Radiography</td>
<td>ACA, CCE, International Chiropractor’s Association (ICA)</td>
</tr>
<tr>
<td>Adjustor 2</td>
<td>Radiography</td>
<td>ACA, CCE, ICA</td>
</tr>
<tr>
<td>Adjustor 3</td>
<td>Radiography</td>
<td>Federation of Straight Chiropractic Organizations (FSCO), Straight Chiropractic Academic Standards Association (SCASA)</td>
</tr>
<tr>
<td>Adjustor 4</td>
<td>Radiography</td>
<td>FSCO, SCASA</td>
</tr>
</tbody>
</table>
Chiropractic pioneers were among the first to use radiography/Spinography to evaluate spinal structural positions. Historical and current chiropractic technique systems taught in the majority of chiropractic colleges and in continuing education courses recommend radiography to assess spinal subluxation and to determine treatment intervention strategies.

In profession wide surveys, Chiropractors have an increased utilization rate of spinal radiography compared to family physicians and non-orthopedic surgeons who practice medicine; this is likely a result of different philosophies, analysis, treatment approaches, and treatment outcomes inherent in Chiropractic. Because a majority of Chiropractors utilize radiographic analysis for biomechanical evaluation of the patient’s structural spinal position/abnormality (subluxation defined in Section V), the use of initial x-rays for biomechanical evaluation of the spine can be considered part of the standard of practice for clinical chiropractic.

Chiropractic professional identity groups and organizations recommend radiography as a primary evaluation/assessment method. Thus, it is our expert panel’s consensus that historically and currently, chiropractic professional organizations, clinicians, systems, and techniques recommend radiographic evaluation of spinal position, kinematics, and abnormalities to comprehensively evaluate and develop treatment interventions for a given patient.
References

25. Palmer BJ. The Subluxation Specific, the Adjustment Specific. Davenport, IA: Palmer College of Chiropractic, 1934.
V. Definition of Subluxation and Average Normal Spinal Alignment

RECOMMENDATION

Vertebral subluxation should be maintained as the primary health disorder that comprises the Chiropractic profession's identity. The 6 structural categories of subluxation presented herein are recommended descriptions for the biomechanical component of vertebral subluxation. Radiography is indicated for the qualitative and/or quantitative assessment of the biomechanical components of these 6 vertebral subluxation categories. When using radiography, a baseline value of the mechanical displacement should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.


Introduction

Historically, there have been many different definitions of vertebral subluxation used by chiropractors and other health care providers. A commonality of chiropractic definitions has been: 1) vertebral misalignment and 2) disturbance of normal nerve function.

In general, chiropractors have long been displeased with the medical profession’s definition of subluxation, which usually has had something to do with translations of single vertebra beyond the limits of the spinal ligaments; i.e., retrolisthesis, laterolisthesis, and thin discs. As an example, the Cervical Spine Research Society defined spinal subluxation as a “nontraumatic condition caused by approximation of vertebrae due to disc degeneration, with concomitant telescoping of articular processes without disruption of joint surfaces” (1983). In some texts, 3 or more millimeters of translation are considered an indication of spinal subluxation. Mechanically, translations are only 3 of the six possible degrees of freedom of spinal motion.

To quote White and Panjabi’s 1978 text, “Subluxation may be defined as a partial dislocation. It is any pathological situation in which there is not a normal physiological juxtaposition of the articular surfaces of a joint. Such situations should be reliably demonstrable radiographically.” This definition implies ligament disruption. When ligament disruption is the only definition of subluxation, then smaller displacements within the range of joint motion, maintained for long periods of time, are eliminated from consideration even though serious soft tissue deformations may result and pathologies created. Also abnormal postural positions and their consequent spinal coupling patterns, which are associated with asymmetrical spinal loading and pathologies over time, are eliminated as possibilities from this White and Panjabi definition.

A review of a few chiropractic definitions does little to clarify the entity of subluxation. For instance, the following persons and groups have all defined subluxation differently: D.D. Palmer, B.J. Palmer, Janse, Lantz, Yochum and Rowe, Harrison et al, Osterbauer, Bergmann and Finer, Cooperstein and Lisi, Owens and Pennacchio, Triano, ICA, ACA, Hildebrandt, Gatterman, and the 1972 Medicare Houston Conference. The Houston Conference was composed of members from the liberal Chiropractic Colleges (ACA affiliates in
1972), DACBRs, and DACBOs. They defined subluxation as, “the alteration of normal
dynamics, anatomical, or physiological relationships of contiguous articular structures.”
We note that they added “dynamics and physiological relationship” to the “alteration of anatomical
relationship” used by the conservative colleges (ICA affiliates in 1972).

In general terms, instead of a precise definition of subluxation, chiropractors have
resorted to vague terms such as “biomechanical aberration” and “loss of mechanical integrity of
the spine” and have attempted to describe the effects of subluxation, such as “histopathology,
myopathology, kinesiopathology, pathophysiology, and neuropathophysiology.”

In July 1996, spinal and extraspinal subluxation was defined through consensus of the
chiropractic college presidents: “Subluxation is a complex of functional and/or structural and/or
pathological changes that compromise neural integrity and may influence organ systems
function and general health.”

However, the past editor of Journal of Manipulative and Physiological Therapeutics, Dr.
Lawrence stated, “Subluxation goes beyond metaphor; it is at the heart of chiropractic. This
being the case, we must follow where our studies take us, never fearing to modify our core
beliefs even when it affects market share or reflects poorly upon our science. Science is mutable;
it changes with new data. So, too, does the chiropractic profession. Efforts to better define and
understand the subluxation can only help but take us into a brighter future,” and “Attempts to
define the term (subluxation) are regularly made, only to fall afoul of political considerations
rather than scientific ones.”

Thus, in the opinion of the current panel of experts, the definition of subluxation by a
consensus of the chiropractic college presidents is another definition of subluxation that falls
short due to an all encompassing political net and a more scientific approach needs to be
considered. The need for a more scientific definition is vital when radiography is utilized as a
measurement of spinal subluxation.

Attributes of Spinal Subluxation

In 1997, Nelson wrote a critique of several attempts to define subluxation. He pointed
out that, “at no point is there a statement or observation that a subluxation is a particular
alteration of anatomy, physiology, etc.” Nelson also stated that attempts to change the name (of
subluxation) to “manipulable lesion,” “loss of function,” etc. are semantic issues, when the real
issue is “whether the concept of subluxation is valid and represents a clinically important
phenomenon.” Also Nelson stated that a theoretical model of subluxation should do at least
three things: 1) A theory should attempt to explain existing phenomena and observations; 2) A
theory should make predictions; and 3) A theory should be testable or falsifiable. He listed 6
attributes that a definition of subluxation must have:

1) It should have some resemblance to its historical antecedents;
2) It should be testable;
3) It should be consistent with current basic science precepts and principles;
4) It should reflect current practice and educational standards (specificity);
5) It should be clinically meaningful (tangible clinical consequences); and
6) It should present a distinct and unique point of view.

Nelson also noted that “spinal lesion” does not fit the requirements. Webster’s defines
“lesion” as a) “injury” or b) “an abnormal change in structure of an organ or part due to injury or
disease.” Thus, lesion (injury) could be the cause of a subluxation or the result (disease) of a subluxation, but does not state what a subluxation is.

Also, it should be noted that several College administrators and faculty have stated that there is no such entity as a vertebral subluxation and the term should be discarded. However, over the years, the ACA (SOS campaign = Save our Subluxation) and ICA have always reaffirmed the use of the term vertebral subluxation.

According to a 2003 study on "How Chiropractors Think and Practice: The Survey of North American Chiropractors," published by the Institute for Social Research at Ohio Northern University, "For all practical purposes, there is no debate on the vertebral subluxation complex. Nearly 90% want to retain the VSC as a term. Similarly, almost 90% do not want the adjustment limited to musculoskeletal conditions. The profession -- as a whole -- presents a united front regarding the subluxation and the adjustment."

Below we will provide an updated scientific definition of 6 different structural subluxation classifications that will satisfy Nelson’s 6 attributes and it will be historically and contemporarily correct. Furthermore, it will be shown that spinal radiography (or other advanced imaging techniques) is the only valid means to assess the presence and magnitude of these 6 structural subluxation classifications.

**Definition of Subluxation from the Practicing Chiropractors Committee**

It is the opinion of the PCCRP panel that practicing Chiropractors have defined subluxation, used it daily in their assessments, in their corrective adjustments and rehabilitative procedures, and in their explanations to patients since 1910. Any definition of subluxation should include the historical concepts used by Chiropractic Clinicians, should be consistent with mathematics and mechanical engineering principles, and it should be valid in terms of the known spinal sciences.

It is the consensus of this panel that the original definition of subluxation derived from the Palmers’ “a bone that has lost its normal juxtaposition causing nerve interference”, is what Chiropractic Clinicians have used daily for approximately 100 years. We will show that this historical “working definition” of subluxation by practicing Chiropractic Clinicians satisfies Nelson’s 6 attributes described above, it is mathematically sound, it is based upon mechanical engineering, it is supportable with current spinal sciences, it is measurable, it is correctable (if degeneration or deformity have not progressed too far), and it will include the specific types of subluxations listed by the Houston “Medicare Conference” in 1972, which derived our Medicare listings for the US Federal Government. Thus, this subluxation definition, “a bone that has lost its normal juxtaposition causing nerve interference”, is simple, partly used already in Federal Guidelines, and it is scientific.

In this section of this Radiological Protocol, we will discuss “Bone out of Place”, but in Sections X & XII of this document, which discusses predictive validity and tissue mechanoreceptors, will be the primary supporting evidence for the statement that “Bone out of Place has inherent functional disturbances and nerve interference”.

The immediate need in this section is to define what it is that Chiropractic Clinicians will be assessing via spinal radiography. To begin, a normal average spinal alignment from which measurements of subluxation can be determined is needed. This comes directly from the fact that “Bone out of place” begs the question what is meant by “in place”?
Average Normal Spinal Alignment

Most health care providers accept the average values as “Normal” from a plethora of physiologic, anatomic, and biomechanical measurements (such as normal blood pressure is 120/80). Similarly, average values as “Normal” from healthy subjects for spinal alignment have been determined and published in the scientific literature. Because an average normal spinal model for each region (cervical spine, thoracic spine, and lumbar spine) was not published until recently, the Chiropractic founding fathers did not have access to any such normal values of segmental and/or global alignment. Thus they had only their intuition to guide them. However, this information is available to us at the present time.

From 1996-2003, normal spinal models were published for each region of the spine.6-11,15 These normal spinal models are of two types, average6-8 and ideal.9-11,15 These models have been criticized by persons denying the very existence of subluxation, and have been suggested to be solely ideal or theoretical in character without clinical utility.21,22,28,36,37 However, average normal spinal models have been developed and published in scientific journals. Furthermore, criticisms addressing these models have been addressed and adequately refuted.6-8,38

In these recent modeling studies of normal individuals, subject x-rays were placed on a view box where a sonic digitizer was used to touch the vertebral landmarks on the x-ray. Specifically, the x-y coordinates of the posterior aspect of the vertebral body landmarks are read and stored in a computer data base. These x-y coordinates from digitization of subject films, are then used in modeling of subject spinal alignments. As a result of this 'curve fitting modeling process', pieces of circles and ellipses were found to closely approximate the alignment of the posterior body margins and thus this average normal spinal model is actually the path of the posterior longitudinal ligament (PLL) from C1-S1 (Figure 1). It is important to note that chiropractors are not the only health care clinicians that are interested in average models of the spine. Recently, orthopedic surgeons have developed an optimization approach to model subject specific sagittal plane spinal curves; application of these models to spinal pain/deformity groups is being done as well.39-42

Before presenting average normal values for each motor unit (two adjacent vertebrae), we note that these average normal models have predictive validity in as much as they can discriminate between normal subjects, acute pain subjects, and chronic pain subjects in both the cervical8 and lumbar spines.6

In the AP/PA view, the spine should be vertical and all end plate lines should be horizontal including occiput, C1-C7, T1-T12, L1-L5, sacral base, and a line at the tops of the femur heads (Figure 2A). These lines are the Gonstead Technique43 wedge lines or also they are the endplate lines from which perpendiculars are drawn in the Cobb analysis, i.e., all wedge lines are parallel and all Cobb angles are 0° in the AP or PA spinal radiographic view. Another way to express this AP vertical alignment of the vertebrae is to state that all centers of mass are vertically aligned. In the cervical spine, this is equivalent to stating that the upper angle, lower angle, and CD angle on the nasium view are 90°, 90°, and 0°, respectively (See Section X Nasium X-ray view). In the thoracic and lumbar spines, this is equivalent to stating that all AP Riser-Ferguson angles (in any spinal region) are 0° (See Section X AP Thoracic, AP Lumbar, and AP Ferguson X-ray views).
In the sagittal view, average normal rotation angles of each motor unit (two adjacent vertebrae) can be derived from drawing lines along the posterior body margins of every vertebrae and measuring the angle of intersection of each pair (Figure 2B). In actuality, these lines represent the slopes in an Engineering analysis of structures taught in Mechanics of Materials. For C1, the sacral base (S1), and the pelvic tilt, lines through these structures are often compared to a horizontal line for an angle of inclination in degrees (Figure 2B). Segmental angles formed at adjacent vertebrae are termed Relative Rotation Angles (RRAs), while global angles (Absolute Rotation Angles are termed ARAs) in each region can be formed by comparing a superior vertebra in a sagittal region to an inferior vertebra. In this way an evaluation of the cervical lordosis (ARA C2-C7), thoracic kyphosis (ARA T1-T12 or ARA T2-T11), and lumbar lordosis (ARA L1-L5) can be measured in degrees. The reliability of these x-ray mensuration procedures will be comprehensively reviewed in Section VIII of the document.
Since the AP alignment dictates zero degrees displacement in all end plate lines and all lines through centers of mass, it is the average normal sagittal angles (RRAs & ARAs) that are of interest. Below, Tables (1-3) present average normal values for the RRAs and ARAs for the three spinal regions, cervical spine, thoracic spine, and lumbar spine. As expressed previously, these average values are from published average healthy subjects’ spinal modeling studies.\textsuperscript{6-8}

**Figure 2AB.** In A, the vertical alignment of the entire head, spine, and pelvis is shown. One can either express this alignment as (a) all wedge lines (end plate lines) are parallel, e.g., all Gonstead wedge angles are zero and all Cobb angles are zero, or (b) all centers of mass are vertically aligned, e.g., all Nasium upper and lower angles are zero in displacement from 90º and all Risser-Ferguson angles are zero. The Risser-Ferguson lines will meet the sacral base wedge line at 90º. In B, sagittal alignment is measured as intersecting posterior vertebral body tangents, which create segmental angles at each pair of vertebra (RRAs) or global angles (ARAs) in each spinal region. Regional global angles are formed by choosing a superior vertebra and an inferior vertebra to intersect the posterior tangents, e.g., ARA C2-C7, ARA T3-T10, and/or ARA L1-L5. Reprinted with permission from Harrison CBP Seminars Inc., Evanston, WY.
Table 1. Sagittal Cervical Average\(^8\) and Ideal\(^9\) Normal Values
(Reported as absolute values, since extension is –Rx)

<table>
<thead>
<tr>
<th>Level</th>
<th>Average Value</th>
<th>Ideal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tz C2-C7 (mm)</td>
<td>4 mm</td>
<td>0 mm</td>
</tr>
<tr>
<td>Segmental Angles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1-Horizontal</td>
<td>29°</td>
<td>29°</td>
</tr>
<tr>
<td>C2-C3</td>
<td>6.4°</td>
<td>9.4°</td>
</tr>
<tr>
<td>C3-C4</td>
<td>6.9°</td>
<td>8.2°</td>
</tr>
<tr>
<td>C4-C5</td>
<td>6.8°</td>
<td>8.2°</td>
</tr>
<tr>
<td>C5-C6</td>
<td>6.6°</td>
<td>8.2°</td>
</tr>
<tr>
<td>C6-C7</td>
<td>7.8°</td>
<td>8.2°</td>
</tr>
<tr>
<td>Global Angles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARA C2-C7</td>
<td>34.5°</td>
<td>42.2°</td>
</tr>
<tr>
<td>Cobb C2-C7</td>
<td>26.8°</td>
<td>NR</td>
</tr>
<tr>
<td>Cobb C1-C7</td>
<td>55.1°</td>
<td>NR</td>
</tr>
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Table 2. Sagittal Thoracic Average\(^7\) and Ideal\(^10\) Normal Values

<table>
<thead>
<tr>
<th>Level</th>
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<th>Ideal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2-T3</td>
<td>3.3°</td>
<td>6.8°</td>
</tr>
<tr>
<td>T3-T4</td>
<td>5.0°</td>
<td>6.3°</td>
</tr>
<tr>
<td>T4-T5</td>
<td>6.5°</td>
<td>5.9°</td>
</tr>
<tr>
<td>T5-T6</td>
<td>5.2°</td>
<td>5.5°</td>
</tr>
<tr>
<td>T6-T7</td>
<td>6.7°</td>
<td>5.2°</td>
</tr>
<tr>
<td>T7-T8</td>
<td>6.2°</td>
<td>5.0°</td>
</tr>
<tr>
<td>T8-T9</td>
<td>4.7°</td>
<td>4.8°</td>
</tr>
<tr>
<td>T9-T10</td>
<td>3.1°</td>
<td>4.7°</td>
</tr>
<tr>
<td>T10-T11</td>
<td>4.4°</td>
<td>4.7°</td>
</tr>
<tr>
<td>ARA T3-T10</td>
<td>37.4°</td>
<td>37.4°</td>
</tr>
<tr>
<td>ARA T2-T11</td>
<td>45.1°</td>
<td>49.0°</td>
</tr>
</tbody>
</table>

Table 3. Sagittal Lumbar Average\(^6\) and Ideal\(^15\) Normal Values (Reported as absolute values, since extension is –Rx).

<table>
<thead>
<tr>
<th>Level</th>
<th>Average Value</th>
<th>Ideal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12-L1</td>
<td>0°</td>
<td>0°</td>
</tr>
<tr>
<td>L1-L2</td>
<td>2.9°</td>
<td>5.1°</td>
</tr>
<tr>
<td>L2-L3</td>
<td>7.4°</td>
<td>6.3°</td>
</tr>
<tr>
<td>L3-L4</td>
<td>11.9°</td>
<td>9.1°</td>
</tr>
<tr>
<td>L4-L5</td>
<td>16.6°</td>
<td>18.5°</td>
</tr>
<tr>
<td>L5-S1</td>
<td>32.4°</td>
<td>33.0°</td>
</tr>
<tr>
<td>S1 to horizontal</td>
<td>39.2°</td>
<td>40.0°</td>
</tr>
<tr>
<td>ARA L1-L5</td>
<td>39.7°</td>
<td>40.0° Rounded Up</td>
</tr>
</tbody>
</table>
**Structural Spinal Subluxation Assessment**

Despite political attempts to the contrary and continual academic tampering, practicing Chiropractic Clinicians have repeatedly used subluxation and “spinal listings” interchangeably as early as 1910, which is when BJ Palmer took the first chiropractic spinal x-ray in the USA. In other words, the spinal listing is the mechanical description of the subluxation. Historically, spinal listings have been composed of letters of the alphabet to represent the direction in which a vertebra has misaligned, e.g., P = posterior, A = anterior, R = right (spinous movement in PA view), L = left (spinous movement in PA view), S = superior, and I = inferior. These directions of misalignment were observed on spinal radiographs as early as 1910. Without an education in engineering, early Chiropractic Clinicians correctly categorized all the possible movements of a motor unit (listing the top vertebra’s movement relative to the vertebra immediately below) as: axial rotation, lateral bending, flexion-extension, anterolisthesis-retrolisthesis, laterolisthesis, and thin discs. Figure 3 illustrates all twelve possible vertebral misalignments in six degrees of freedom, but with listings expressed in engineering terms as rotations in degrees (Rx, Ry, Rz) and translations in millimeters (Tx, Ty, Tz).

In 1972, the liberal Chiropractic Colleges’ Houston Medicare Conference chose 17 spinal displacements as spinal subluxations to be used by the Federal government in defining spinal subluxation for re-imbursement of services to Chiropractors. These were:

A. **Static intersegmental subluxations**
   1. Flexion malposition
   2. Extension malposition
   3. Lateral flexion malposition
   4. Rotational malposition
   5. Anterolisthesis
   6. Retrolisthesis
   7. Altered interosseous spacing (decrease/increase)
   8. Osseous foraminal encroachment

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**Figure 3.** These are the misalignments that early Chiropractors observed on spinal x-rays after 1910. These were later described as rotations and translations in an x-y-z coordinate system in the literature in the 1970s. Using the Panjabi et al.’s coordinate system (Y vertical, X to the left, Z forward), axial rotation is ±Ry, lateral flexion is ±Rz, and flexion-extension is ±Rx, while left and right latero-listheses are ±Tx, vertical translation (thin discs and traction) are ±Ty, and antero- and retro-listheses are ±Tz. Reprinted with permission: Harrison DE et al. Spinal Biomechanics for Clinicians, Vol I., Evanston, WY: Harrison CBP Seminars, 2003
B. Kinetic intersegmental subluxations

9. Hypomobility (fixation)
10. Hypermobility
11. Aberrant motion.

C. Sectional subluxations

12. Scoliosis and/or alteration of curves secondary to musculature imbalance
13. Scoliosis and/or alteration of curves secondary to structural asymmetries
14. Decompensation of adaptational curvatures
15. Abnormalities of motion.

D. Paravertebral subluxations

16. Costovertebral and costotransverse disrelationships
17. Sacroiliac subluxations

In the above list, it is noted that (1) and (2) are ±Rx, (3) is ±Rz, (4) is ±Ry, (5) and (6) are ±Tz, (7) is ±Ty, (8) happens over time from (1) through (7) and is a pathology not a subluxation, and the Houston Conference members omitted the degree of freedom associated with laterolisthesis, which is ±Tx. Again it is noted that the Houston Conference members added (9)-(11) and (15), abnormal motion, to the list of possible subluxations, which, traditionally in the 8 conservative Chiropractic Colleges, was “bone out of place”. Of course the “Sectional Subluxations” are composed of movements of individual segments in 1 or more of the 6 Degrees of Freedom as a choice of one member (+ or -) from any or all of ±Rx, ±Ry, ±Rz, ±Tx, ±Ty and ±Tz.

It is important to note that using the average normal spinal model in Figure 1 and Tables 1-3, these displacements (listings) can be measured in degrees of rotation and millimeters of translation. Additionally, using the methods suggested in Figure 2A (Gonstead, Cobb, Risser-Ferguson, upper and lower angles on the nasium), it is possible to measure “Sectional Subluxations” (regional subluxations) in degrees of displacement from normal.

However, these “Sectional Subluxations” are more clearly described in engineering terms as buckling, i.e., snap through buckling = sagittal buckling in harmonics or eigenvalues and their eigensolutions (types of “S”-curves), Elastic buckling of a column, or Euler buckling of a column.44-47

Since the current guideline document deals solely with vertebral subluxations the extraspinal or “paravertebral subluxations” (#16 and 17 in the above list) will not be discussed.

We have presented the Houston Conference Medicare subluxation definitions13 for a historical perspective, pointing out that in our present time these displacements can be measured from the average normal spine, and for possible inclusion in a more precise list of subluxation types.

Subluxation Types

Using the reference frame from Panjabi et al.,22 there are four types of observed postural and spinal segmental subluxations (displacements), which have been adequately described in mechanical engineering terms and verified by biomechanical investigations. In 1998, Harrison et al5 presented a detailed review of the literature of these four types. In the current document, we add to the four types of subluxation discussed by Harrison et al5 and present these as types of structural/mechanical displacements of the spine (“bone out of place”):
1. **Segmental subluxations**: These are the segmental displacements from C1-S1 measured from the vertebra above relative to an origin located in the vertebra immediately below. These vertebral spinal subluxations are listed in terms of \( R_x, R_y, R_z, T_x, T_y, T_z \).\(^{43,48-51}\) (See Figure 3). Triano\(^48\) discussed these segmental displacements in terms of a buckling phenomenon but only discussed their post-buckled behavior (kinematic alterations) while neglecting the fact that these are associated with static displacements described as their respective post-buckled modes. Furthermore, Triano\(^48\) failed to acknowledge the fact that the only valid way to identify these segmental displacements (post-buckled segmental modes or kinematic alterations) is by radiographic means.\(^{43,49-51}\)

2. **Postural main motion and coupled motion**: Postural displacements found in neutral resting stance are completely described as rotations and translation displacements of the head, thoracic cage, and pelvis. The majority of these displacements are concomitantly associated with spinal coupling/displacement patterns.\(^5,52-56\) Each postural displacement has a unique spinal displacement pattern, with which it is normally associated. (See Figure 4). When discussing postural rotations and translations as global subluxations, we do not mean dynamic range of motion, but the occurrence of such positions in the neutral resting posture. Of interest, postural displacements from the neutral spine have been modeled as a ‘simple’ elastic buckling phenomenon.\(^56\)

3. **Snap-through buckling in the sagittal plane**: The alterations in the regional sagittal curves of cervical or lumbar lordosis to kyphosis and “S”-curves and, to some extent, changes in thoracic kyphosis to hypo- or hyper-kyphosis have been found to be consistent with the engineering Snap-through type of buckling.\(^57-69\) According to Nightingale et al\(^60\), referring to Chen and Lui\(^45\), “In a column with a fixed base, buckling is evidenced by an abrupt decrease in measured compressive load with increasing deflection and moment. Snap through buckling is characterized by a visible and rapid transition from one equilibrium configuration to another”.

Snap through buckling can occur in 1 of 3 ways: a) an abrupt impact load applied to the head, ribcage, or butt, b) an overload event such as bending forward and lifting a very heavy object, or 3) an inertial loading event causing rapid acceleration and inertial loads to the spinal segments such as a rear end motor vehicle accident.\(^57-69\) Increased complexity of the snap-through buckling is delineated in terms of the shape of the curves. An S-shape in any region (cervical, thoracic, lumbar) is the 1st order buckled mode, flexion-extension-flexion in any region is the 2nd order buckled mode, etc. In experiments, 2nd order and higher buckled modes are caused by dynamic loading and are associated with large increases in potential energy whereas 1st order buckled modes have been produced under static and quasi-static loading experiments. See Figure 5.

4. **Euler buckling in AP/PA view**: This type of structural displacement is generally where the structures of the lower most segments in a spinal region experience some failure, e.g., axial rotation and/or lateral flexion of L4 & L5.\(^5,70-72\) These displacements are generally localized to the distal spinal regions of the cervical, thoraco-lumbar, and lumbo-pelvic and are generally associated with sub-catastrophic (non-complete tears) and sometimes catastrophic (macro) tears in the surrounding ligaments. These occur under similar loading circumstances as Snap through buckling detailed above. See Figure 6.
5. **Scoliosis:** Recently, the pathomechanics and perhaps the etiology of the non-neurogenic forms of scoliosis have been described by a ‘slow-loading’ buckling mechanism. There are multiple different types, locations and complexities of scoliosis.

6. **Static or dynamic segmental instability:** These are the segmental displacements depicted in Figure 3 but are at the limit of or past the limit for range of motion of the functional spinal unit. These are associated with significant ligamentous trauma. This information is detailed in Section X of this document under dynamic imaging and flexion/extension radiography.

These 6 types of subluxation are mechanical descriptions for the allowable spinal displacements that can occur. Using the average normal spinal model, inside normal upright stance, that we precisely defined in Figure 1, these 6 types of displacements can be quantified. It is an important feature that each one of the structural subluxations (except for instability, number 6 above) is a displacement that occurs within the allowable range of motion of the functional spinal motion segment. Thus, these 5 subluxations are static and dynamic mechanical displacements that are sustained within the range of joint motion. Also, we note that the above 6 types of structural subluxation are listed in increasing complexity of the displacement until we reach complete ligamentous failure or instability (number 6).

We must emphatically reiterate that all 6 of the above structural subluxations require radiographic analysis for valid identification and quantification. Surface contour assessments for the sagittal spinal curves are invalid in the cervical region, questionable in the lumbar region, although some can predict gross thoracic kyphosis. However, these methods are not designed to replace initial spinal radiographs, and cannot readily determine segmental alignment. Next we compare our definitions of subluxation against Nelson’s 6 attributes.

![Figure 4. Postural Main Motion and Coupled motion. In A, the posture of right head translation is shown. In B, the skeletal animation from the posterior to anterior view is shown depicting the opposite lateral bending coupling motions in the mid-low cervical spine versus the mid-upper cervical spine. In C, a patient radiograph is shown with the coupling patterns for right head translation. Reprinted with permission from Harrison CBP Seminars Inc., Evanston, WY.](image-url)
Subluxation Definitions Compared to Nelson’s Attributes

Our ‘new’ definition of subluxation with its 6 basic types will now be evaluated using Nelson’s 6 attributes. The fact that segmental positions (spinal listings) are important in spinal coupling, sagittal buckling, Euler buckling, and segmental instability provides an obvious resemblance to chiropractic’s historical antecedents of subluxation. When whole regions are measured as displacements from normal, these segmental displacements are the building blocks that comprise global spinal areas.

This new subluxation definition is testable (Nelson’s 2nd attribute) because, using rotations and translations of posture and spinal segments, measurements can be made in 3-D for posture and in 2-D radiographic projections (Section VIII and X provides these measures). The review published in 1998 and the current brief review of the scientific literature, provides the support for Nelson’s 3rd item; “It should be consistent with current basic science precepts and principles.”
For Nelson’s 4th attribute, it is obvious that abnormal postures composed of rotations and translations in 3-D, spinal buckling, and segmental instability, are unique spinal positions. Thus, the correction/reduction of these positions requires specific opposite transformations (rigid body movements caused by chiropractic adjustment forces) in a mechanical engineering analysis. The information, presented herein, does not yet “reflect current practice and educational standards”; but this is not an inherent problem with the definitions of subluxation stated here. However, these concepts are taught in approximately 1/3 of the Chiropractic Colleges in the United States.

For Nelson’s 5th attribute, “it should be clinically meaningful”, there are many studies on adverse mechanical stresses/strains in the CNS, many studies on the adverse loads (stresses/strains) on the spinal tissues, and many studies on the adverse loads on mechanoreceptors for displacements from the average normal spine depicted in Figure 1. Davis’ Law (soft tissue remodels to stress) and Wolff’s Law (bone remodels to stress) provide enough “clinically meaningfulness”. This area of “clinically meaningful”, adverse health consequences and studies which show that deviations from the ideal are associated with pain or other disorders will be expanded upon in Section X and under each specific radiographic view and in Section XII on joint mechanoreceptors and pain.

For Nelson’s 6th attribute, “it should present a distinct and unique point of view”, these 6 types of subluxation, are unique rigid body movements, taught as possibilities in Linear Algebra (rotations and translations) and as different types of buckling in mechanical engineering. It provides the basis for chiropractic to remain a unique healthcare field. Nevertheless, segmental correction, posture correction, and correction of the sagittal spinal curves have been associated with a multitude of health benefits in the literature to date. Evidence for this statement will be provided in a later section of this document (see Section X).

Anatomic/Anomaly Variants Affecting Spinal Geometry

An important topic when discussing our average spinal models’ application to the human population is a consideration of anatomical variations in a given persons spinal anatomy. There are several known anatomical variants of human spinal anatomy that affect spinal alignment/geometry, however, there are several variants that do not. Significant progress has been made in understanding the correlations between a variety of anatomical variants and spine geometric alterations; Chiropractic clinicians and researchers have played a significant role in this area of investigation.

Problematically, this area of investigation has given a subgroup of publishing Chiropractic Radiologists (DACBR’s) and academics an avenue for open ended criticism and cause to berate and chastise chiropractic techniques and clinicians who are interested in structural spinal rehabilitative patient treatment and outcomes. In fact, instead of looking at the evidence for and against specific anomalies and spinal geometric alterations, these individuals have fabricated cause and effect relationships, based their criticisms on flawed investigations, and have relied mainly on Class V (expert opinion) evidence without acknowledging the progress innovative chiropractic pioneers and clinicians have made in accommodating the variants.

For example, in a recent 2005 Chiropractic text, Peterson and Hsu, claim that chiropractic roentgenometric measurement of spinal subluxation is “…controversial within the profession, particularly because the impact of natural and normal asymmetries with the body on these measurements is not known.” In support of their statement, the opinion article by Haas et
al\(^95\) and the investigation by Peterson et al\(^{96}\) are offered. Concerning the Haas et al\(^{95}\) opinion article, a claim was made that ‘natural asymmetry’ of the spinous processes would in fact alter spinal geometry in the AP view. However, no evidence was provided for their statement of cause and effect. In contrast, over two decades ago, Farfan\(^{100}\) found that when the spinous process is asymmetrical, the entire vertebral architecture will change and keep the lamina junction in line with the structural center of the vertebral body. This means the center of mass of the vertebral body will remain approximately the same. Farfan\(^{100}\) states “It would appear that in the development of the vertebra, asymmetrical body growth is compensated for by asymmetric growth of the neural arch”. In 2000, Harrison et al\(^{38}\) pointed out the erroneous statement by Haas et al. This panel questions why Peterson and Hsu\(^{37}\) continue to ignore this?

The second investigation offered by Peterson and Hsu\(^{37}\) to criticize the chiropractic clinicians’ use of spinal radiography, is the study by Peterson et al.\(^96\) With a small sample size and no segmental analysis of cervical lordosis, Petersen et al\(^96\) claimed that alterations in the angle of the facet surfaces in the sagittal plane caused a reduction in the magnitude of the cervical lordosis. The origin of claiming that facet architecture/angles influence the cervical curve can be traced to a 1977 self-published text by MacRae.\(^{97}\) In this 1977 text, only Class V evidence is given for MacRae’s\(^{97}\) hypothesis. In a letter to an editor, Winterstein\(^{98}\) claimed that “short pedicles and vertically facing articular facets predispose to a cervical hypolordosis or kyphosis.” Winterstein\(^{98}\) offered no references for such statement but presumably was referring to MacRae (1977).\(^{97}\) In line with previous claims, the results from Peterson et al\(^96\) were challenged in a letter by Harrison et al\(^{101}\) for several reasons but these criticisms still go ignored. More importantly, Harrison et al\(^{102}\) performed a much needed investigation using 252 subjects, where the correlation between articular pillar height, facet surface sagittal plane angles, and the shape of the dens and the segmental and total cervical spine curvature was determined. Harrison et al\(^{102}\) state,

“In contrast to chiropractic radiology paradigms in the literature, we found no statistical correlation with hyperplasia of the cervical facets (superior and inferior facet surfaces that diverge to the posterior) and any segmental or global angle of cervical lordosis. Additionally, there is no correlation with the vertical heights of the cervical facets and any segmental or global angle of cervical lordosis.”\(^{102}\)

In light of the above, the current Practicing Chiropractic Panel of experts hopes that intellectual honesty and professional duty will create a shift in these happenings.

As stated previously, there are spinal anatomical variants that do affect the geometry of the spine. These include the following:

1. Sagittal plane wedge angles of the vertebral bodies,\(^{103-105}\)
2. Coronal plane wedge angles of the vertebral bodies (hemi-vertebra),\(^{114}\)
3. Anomalies of the skull condyles,\(^{99,106-110}\)
4. Transitional vertebra at L5-S1,\(^{111,112}\)
5. Congenital and surgical blocked vertebra,\(^{113}\) and
6. Pelvic/sacral morphology.\(^{39-42}\)

Chiropractic pioneers (clinicians and researchers) and other health care physicians are on the forefront of investigating spinal anomalies, learning to identify them via radiographic means, and developing treatment strategies that account for the anatomical variances.\(^{105-108,111}\)
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VI. Review of X-ray Usage and Guidelines by Orthopedic Surgeons, Family Practice Physicians, American Chiropractic College of Radiology (ACCR), and Medical Radiologists (ACR)

RECOMMENDATIONS

By way of radiography guideline reviews, the PCCRP finds its’ guidelines to be consistent with guidelines put forth and adopted by the American Academy of Family Physicians, the American Medical Association, the American Academy of Orthopedic Surgeons, the American College of Radiologists, and, to some extent, the American College of Chiropractic Radiologists and French Society of Orthopaedic and Osteopathic Manual Medicine. Thus, we recommend the adoption of the PCCRP Guidelines in Section II for current chiropractic clinical practice standards.

Supporting Evidence: Literature Surveys and Guideline Reviews.

Introduction

In our beginning sections, it has been pointed out that a subgroup of Chiropractic Radiologists (DACBRs) and some chiropractic academics are attempting to restrict the radiographic privileges of Chiropractors in a variety of countries. This attempt to restrict Chiropractic radiographic privileges is coinciding with a general attempt to limit radiographic analysis of the spine in the healthcare arena; this is likely driven by financial motives of 3rd party payers. To investigate this possibility, we will cite surveys, position statements, and protocols by other healthcare providers. The reader will note Managed Care Organizations (MCO’s) and insurers are trying to cut costs and maximize profits by limiting x-ray, CT, and MRI exams in Chiropractic and other health care disciplines as well. In general, there is a movement in spinal health care to attempt to limit x-ray exams to “red flag” cases only.

First, we remind the reader of the information brought forth in Section III, IV, V, and Section X, where it was shown that the ‘red flag’ policy promoters have ignored the facts that this paradigm does not consider the difference in spinal analysis and treatment strategies used by Chiropractors compared to medical interventions for this population of patients and that a large body of evidence has been ignored by the ‘red flag’ camps. To begin, we will elucidate that the information a subgroup of DACBRs are publishing in the general chiropractic literature is contradicted by their own organizations guidelines (American College of Chiropractic Radiologists or ACCR).

By way of a literature review, it is apparent that the publishing subgroup of DACBR’s is adamantly against the chiropractic use of radiography to evaluate spinal subluxations. For example, even though Yochum and Rowe, in their 1987 text, devote approximately 50 pages to line drawing analysis, the lines discussed are generally visualized orthopedic lines and, mostly, are not for measurement of spinal subluxation as delineated in Section X of this document. Yochum and Rowe stated that there is “inherent, uncontrolled error” in: a) image un-sharpness, b) projectional geometric distortion, c) patient positioning, d) anatomic variation, e) locating standard reference points, and f) observer error.

It is the PCCRP panel’s position that to not radiograph a patient with probable spinal subluxation has far more potentially negative impact upon the health of the patient than the exposure to ionizing radiation has on the human organism (Section VII). The teachings in the some of the Chiropractic colleges are to x-ray the point of pain and the benefit to risk ratio in this
common practice is heavily weighted in favor of x-ray examination of the spine, especially in symptomatic cases. However, in recent years, it has been observed that several chiropractic radiologists and academics, such as Hariman, Sigler and Howe, Schultz and Bassano, Phillips, Bussieres et al, Taylor, Harger et al, MacRae, Kettner and Guebert, Peterson and Wei, Peterson et al, Peterson and Hsu, Mootz et al, Deltoff and Kogan, and Haas et al claim that Chiropractic Clinicians:

1. Are over-exposing the public,
2. Take unnecessary initial x-rays,
3. Are borderline criminal for taking post treatment x-rays,
4. Have no evidenced support for subluxation assessment via radiography,
5. Should only recommend spinal radiography in “Red Flag” cases, and
6. Use of x-rays is not supportive in deriving the sequence of care to be given to an individual patient.

Problematically, the radiography textbook chapters (authored by DACBRs Phillips, Peterson and Hsu, Yochum and Rowe, and Taylor and Resnick) and journal publications (authored by a subgroup of DACBRs and group of chiropractic academics) are used by MCO’s (such as ACN and ASHN) to deny coverage for radiology services for patients seeking chiropractic care.

Now that we have outlined the position of a subgroup of DACBRs and chiropractic academics’ opinions as to radiographic usage in Chiropractic practice (“Red Flags Only”), we will provide a review of different health care professional’s and professional organizations radiographic guidelines. There are several health care provider organizations that have radiographic privileges, and who have published information on radiographic utilization and protocols of radiographic procedures:

1. American College of Chiropractic Radiologists (ACCR),
2. Chiropractic College of Radiologists of Canada (CCRC),
3. American Academy of Family Physicians (AAFP),
4. American Medical Association (AMA),
5. American Academy of Orthopedic Surgeons (AAOS),
6. American College of Radiologists (ACR),
7. U.S. Agency for Health Care Policy and Research (AHCPR) Guidelines,
8. Danish Institute for Heath Technology Assessment (DIHTA),
9. Royal College of General Practitioners (RCGP) Acute Low Back Pain Guidelines,
10. The Reed Group Neck Pain Guidelines (RGNPG),
12. Council on Chiropractic Practice Clinical Practice Guidelines (CCPCPG),

**American College of Chiropractic Radiologists (ACCR)**

Unlike attempts to restrict spinal radiographic procedures for practicing Chiropractic Physicians by a sub group of publishing DACBR’s, the American College of Chiropractic Radiologists (ACCR) has put forth a more clinically supportive guideline for spine radiography use in clinical practice of chiropractic. We note that there are approximately 180 Chiropractic Radiologists that belong to the ACCR and most of the ‘publishing DACBR’s’ are members of
this organization. We reprint the first four of the ACCR position statements on general spine radiography and bending films for completeness:

1. “Routine radiography of any patient should not be performed without due regard for clinical need.
2. Any offer or advertising of free x-rays to actual or potential patients shall be accompanied by a statement that, to avoid needless health hazards associated with ionizing radiation, no such free x-ray will be given unless there is a prior observable clinical need for it.
3. Avoidance of split screen radiographic techniques or other mechanisms which compensate for tissue thickness by altering the screen or the light emission from the screens, such as the occluding of one of the screens of the cassette, is recommended.
4. Repeat radiographic evaluation of the patient should not be undertaken without significant observable clinical indication, as determined by, the treating chiropractic physician.”

ACCR Lateral Bending Stress Radiography Guidelines:

1. “Are reserved additional views, not considered as part of the initial routine radiographic examination; unless specific trauma or biomechanical dysfunction is documented by history or clinical evaluation which suggests findings unattainable by other means.
2. Are performed initially only in those patients where prior treatment has been unsuccessful or where objective clinical findings or treatment resistive symptom expression suggests an as yet undiscovered occult pathology.
3. Are performed only of the cervical and lumbar spines.
4. Are to be performed sectionally only in the cervical and lumbar spine, unless used to demonstrate flexion of a scoliosis.”

It is interesting to note that in statements 1, 2, and 4, the ACCR clearly acknowledges the fact that radiographic utilization on a given patient should be solely determined by the treating chiropractic clinician based on clinical need. The clinical need is specific to the individual, but a very large volume of scientific literature supports the chiropractic clinicians’ use of radiography to evaluate the spine in all presenting patients that fit the guidelines as described in Section II (for the support of this, see sections X and XII).

In contrast, to the ACCR’s official guideline position statements, a subgroup of DACBR’s have chosen to ‘take the chiropractic clinician out of the decision making process’ and have elected to ignore the volume of evidence that points to the clinical utility, reliability, and validity of chiropractic radiography for subluxation analysis. Furthermore, based in large part on the published works of this sub group of DACBR’s, MCO’s (ASHN) have mandated that clinicians cannot ascertain appropriate radiography at all (as set forth in Section II) and thus, the treating chiropractic clinician’s role in patient care is eliminated.

Chiropractic College of Radiologists of Canada (CCRC)

The Chiropractic College of Radiologists of Canada (CCRC) can be considered a Canadian branch of the ACCR. However the CCRC is comprised of several non Canadian
international members. There are only approximately 35 living members of the CCRC. Their\textsuperscript{51} guidelines are reflective of the ACCR’s with a few exceptions:

1. The CCRC emphatically denounces chiropractic’s use of initial x-ray examinations as a routine procedure and from patient request,

2. **Full Spine Radiography**: “The utility and effectiveness of the 14 x 36 radiograph has been well documented in chiropractic literature. It definitely has a place in the study of spinal curvature and many types of subluxation patterns.”\textsuperscript{51}

3. Their\textsuperscript{51} Full Spine recommended series include: An A/P full spine and three neutral laterals (cervical, thoracic and lumbar),

4. CCRC Policy on Computer Assisted Analysis of X-rays was rated as “investigational”.\textsuperscript{51}

5. Videoflouroscopy (VF): “Videoflouroscopy is a useful imaging modality for the demonstration of spinal intersegmental joint dysfunction.” The minimum VF examination should include three repetitions and all VF exams should be videotaped. Lumbar views are not recommended but cervical VF’s should include:

   - Head nodding,
   - Full range “forced” flexion and extension,
   - Relaxed flexion and extension,
   - Oblique right and left full range “forced” flexion and extension,
   - Additional exams can include: right and left lateral flexion (open mouth and lower cervical),
   - Additional exams can include: alar ligament assessment in lateral view, nodding, right and left lateral flexion open mouth, and passive stress views.\textsuperscript{51}

The CCRC\textsuperscript{51} elaborates on the use of chiropractic radiology by offering their position statement that patient age groups should dictate the type of radiographic examination that is performed. They\textsuperscript{51} offer different recommendations based on the ages 0-10 years, 10-18 years, 18-40 years, and above 40 years of age. The CCRC\textsuperscript{51} provides no scientific literature supporting any of their position statements on chiropractic radiography recommendations. Second, the CCRC\textsuperscript{51} has contradicted the guidelines of their parent ACCR\textsuperscript{29,30} organization and have removed the Chiropractic Clinician from the decision making process for the attainment of initial spinal radiographs. Lastly, the CCRC position statement regarding computerized or computer assisted analysis of spinal radiographs is in complete opposition to the available scientific literature on this topic. For instance, in Section II and Section VIII of the PCCRP Guidelines, the reliability and validity of computer assisted radiography analysis was reviewed and found to be at least as good as ‘traditional by hand’ assessment methods.

Recently certain members of the (2004-2006) CCRC\textsuperscript{52} have begun an 8 phase, standardized approach\textsuperscript{60-64} to validating an even more restrictive radiological guideline of “Red Flags” only. This group of members CCRC\textsuperscript{53} have finished phases 1-3 (Literature review, Guideline development, First external review) and are working on phase 4 (Consensus panel of
international experts). These new “Red Flags” only radiology guidelines are estimated to be finished by fall 2006.

American Academy of Family Physicians (AAFP)

In 2006, the American Academy of Family Physicians published a Radiology Position Paper on their web site. They stated, “Most family physicians provide the majority of patient care in the outpatient setting. Diagnostic radiographs are an integral part of the evaluation and management of acute and chronic illnesses for patients seen in the office. Those practices that have radiology services on-site usually do not have a radiologist on staff, so the family physician orders and interprets the radiographs, and then renders patient care based on the initial interpretation.” The AAFP web site states:

1. “A majority of family physicians is estimated to have radiography equipment in their offices at this time.
2. Patient care is improved when the family physician is able to fully integrate the patient's history and physical examination with contemporaneous interpretation of diagnostic imaging and other diagnostic studies.
3. Family physicians, like other physicians who use diagnostic radiography in their evaluation of patients, are entitled to appropriate compensation for their services.
4. Initial radiologic evaluation of a large variety of acute and chronic conditions is appropriately performed in the family physician’s office, with referral to another facility for more extensive imaging, if necessary.”

The number of U.S. family physicians with radiology equipment in their offices has not been reported, but a 1988 survey of Minnesota family physicians found that 87.3 percent had on-site radiographic equipment. An unpublished study in 1996 found that 76 percent of Wisconsin family physicians have radiographic equipment in their office and 87 percent have this equipment in the same building. Based on the distribution of non-radiologists’ share of office radiology work broken down by state, Minnesota (43 percent) and Wisconsin (55 percent) were close to the average for the entire United States (46 percent). The limited data suggest that a majority of family physicians use radiographic equipment in their offices.

American Medical Association (AMA)

While the American Chiropractic Association allows fringe statements by the DACBRs to go unchallenged, reimbursement and legal privileges are reduced. In contrast, the American Medical Association (AMA) reaffirmed a policy regarding reimbursement for CT scans and other procedures for their members, stating that "The AMA opposes denial of a physician's right to perform specific services or be compensated for such services solely on the basis of his specialty designation.”

American Academy of Orthopedic Surgeons

Chiropractors who are interested in spinal restoration through correction of spinal subluxation are structuralists, much in the manner that an orthopedic surgeon would be. The American Academy of Orthopedic Surgeons approved a position statement in December 1995 regarding office radiograph performance and interpretation which concludes that "The American Academy of Orthopedic Surgeons believes that orthopedists are entitled to adequate compensation for the cost and work involved in providing musculoskeletal radiographic studies
in their offices. Any policy which prohibits orthopedists from performing and interpreting radiographs in their offices interferes with the patient's ability to receive optimal care.\textsuperscript{3}

**American College of Radiologists (ACR)**

Like the DACBR’s ACCR, the Medical Radiologists have an organization called the American College of Radiologists (ACR). The ACR, however, has approximately 30,000 medical radiologists. The ACR has published guidelines that support Family Physicians, Surgeons, and Neurosurgeons’ use of routine spinography. For example, effective on January 1, 2003, the American College of Radiology (ACR) published their updated “ACR Practice Guideline for the Performance of Spine Radiography in Children and Adults.”\textsuperscript{4}

It is of interest to list the indications for spine radiographs in children and adults advocated by ACR. ACR stated that their “Indications include, but are not limited to:

A. All anatomic regions

1. Trauma to, or potentially involving, the spine.
2. Pain or limitation of motion.
3. Planned or prior surgery on the spine.
4. Evaluation of suspected primary and secondary malignancy.
5. Arthritis.
6. Suspected congenital anomaly of the spine and syndromes associated with spinal abnormality.
7. Evaluation of spinal abnormality seen on other imaging studies.
8. Follow-up of previous spinal abnormality.
9. Suspected spinal instability.

B. Cervical spine

1. Shoulder or arm pain suspected to result from radiculopathy.
2. Occipital headache

C. Thoracic Spine

1. Pain radiating around the chest wall
2. Osteoporosis; compression fractures.
3. Evaluation of scoliosis and kyphosis

D. Lumbar spine

1. Pain radiating into the legs.
2. Osteoporosis; compression fractures.
3. Evaluation of scoliosis and kyphosis,
4. In children, limping or refusal to bare weight and in children with hip pain.\textsuperscript{4}

In these ACR Consensus Guidelines for Spine Radiography for each of the areas listed (All anatomical regions, Cervical Spine, Thoracic Spine, and Lumbosacral Spine), ACR stated that four of their indications for Spine Radiography include, but are not limited to, pain or limitation of motion, arm pain, radiating pain around the chest wall, pain radiating into the legs.\textsuperscript{4}

These are of interest to the Chiropractic Practitioner, since these four indications cover almost every patient that we collectively see on a yearly basis.

While the Panel of Clinical Chiropractic Experts named in this present document of Radiographic Protocols for Chiropractic Clinicians agrees with the above ACR statement for the minimum indications for Spine radiography as a consensus,\textsuperscript{4} some of these ACR minimum indications are for surgery and/or are “Red Flags” and thus are not of primary interest to the
Chiropractor attempting to assess vertebral subluxations (defined in Section V) using a radiographic evaluation. In Sections X and XII of this document, we will provide the evidence-based support for Spinography as a requirement in the presence of any abnormal posture, axial pain, and/or radicular pain.

**U.S. Agency for Health Care Policy and Research (AHCPR) Acute LBP Guidelines**

According to the AHCPR Guidelines: "The use of lumbar x-rays to screen for spinal degenerative changes, congenital anomalies, spondylolysis, spondylolisthesis, or scoliosis very rarely adds useful clinical information. Only 1 of 2,500 x-rays detects something not suspected on history and physical examination that has an impact on patient care." This position statement was based solely on the acute presentation of low back pain of less than 4-weeks duration. Three of the AHCPR’s Chiropractic relevant position statements are reprinted here:

- **Plain X-rays are not recommended for routine evaluation of patients with acute low back problems within the first month of symptoms unless a red flag is noted on clinical examination.**

- **Plain X-rays of the lumbar spine are recommended for ruling out fractures in patients with acute low back problems when any of the following red flags are present: recent significant trauma (any age), recent mild trauma (patient over age 50), history of prolonged steroid use, osteoporosis, or patient over age 70.**

- **The routine use of oblique views on plain lumbar X-rays is not recommended for adults in light of the increased radiation exposure.**

To reiterate, the AHCPR position statements only apply to ‘acute uncomplicated low back pain of less than 4 weeks duration’. Problematically, many chiropractic authors, such as Kato, have misrepresented the AHCPR guidelines in an attempt to apply them to multiple patient conditions.

A major contention with the AHCPR guidelines is the undertone that acute low back pain (LBP) is a self limiting condition. One of the original articles to which the self limiting nature of LBP can be traced comes from Dixon, where a “90% recovery” of acute LBP was found and was based on a record review in one general practice. However, the inference that a patient has completely recovered based on record review is clearly not supportable. In fact, there is no evidence supporting the claim that 80–90% of LBP patients become pain free within 1 month. A minimum of 75% of patients with acute uncomplicated LBP will continue to have problems. At 3 and 12 months follow up, only 39/188 (21%) and 42/170 (25%) respectively will be recovered. (See Section III for a more detailed review of natural history of LBP).

**Royal College of General Practitioners (RCGP) Acute Low Back Pain Guidelines**

The Royal College of General Practitioners (RCGP) has adopted the AHCPR acute low back pain guidelines in their entirety.

**Danish Institute for Heath Technology Assessment (DIHTA) Low Back Pain Guidelines**

The DIHTA have presented guidelines for the utilization of spinal radiography in lower back conditions. These DIHTA guidelines are very similar to the AHCPR. The DIHTA panel contends that radiography “…does not provide any meaningful information for the
majority of patients, as x-ray findings generally correlate poorly to symptomatology.” In the acute case of LBP, the DIHTA recommendations state:

- “Only in circumstances where the health professional suspects the presence of infection or other inflammatory conditions, fractures or cancer will x-rays provide information of importance regarding further examination procedures and treatment.”

However, the DIHTA also included information on the use of radiography in cases of chronic lower back pain; whereas the AHCPR guidelines only discussed acute low back pain of less than 4 weeks duration. Regarding chronic low back pain, the DIHTA recommends:

- “That x-rays should only be generally entertained if the low-back pain has been present for at least four weeks.”

Reed Group Neck Pain Guidelines (RGNPG)

In 2005, the Reed Group offered an evidenced based return to work guideline of those suffering from neck pain. While the RGNPG’s focus was on treatment and early return to work, they offered a very short summary of their position on cervical spine radiography. According to the RGNPG:

“Plain x-rays of the cervical spine may be indicated acutely if severe trauma has occurred and fracture or instability suspected. X-rays are ordered if the symptoms have persisted for 30 days or more.”

The RGNPG’s are not specific to a given health care provider and do not offer any further information on cervical spine radiography.

French Society of Orthopaedic and Osteopathic Manual Medicine (SOFMMOO)

In 2003, the French Society of Orthopaedic and Osteopathic Manual Medicine (SOFMMOO) met to discuss and develop guidelines for spinal radiography that were specific to the intervention of “spinal manipulative therapy”. The SOFMMOO noted that previous guidelines dealt solely with ‘diagnostic radiography’ for diseased conditions, primarily focused on acute low back pain, and ignored the difference in the treatment between traditional medical standard care versus spinal manipulative therapy provided by manual medicine physicians. The SOFMMOO recommendations for spinal radiography are provided:

1. **Lumbar spine and sacrolilac region:** The SOFMMOO adopted the ‘Red Flag’ guideline for acute low back pain similar to the AHCPR. However, SOFMMOO listed two exceptions:
   A. “Firstly, in subjects between 20 and 25 years of age, an aneurismal bone cyst may be present. Since, under these circumstances, manipulation carries a certain risk, subjects in this age group should be routinely X-rayed.”
   B. “Secondly, a patient without any red flags may be anxious to have X-rays done. If manipulation is being considered, it would appear wise to comply with the patient’s wishes, so as to provide reassurance on the condition of his or her spine.”

2. **Thoracic spine:** “Thoracic pain is a red flag in some (especially the British) guidelines; patients with thoracic pain should be X-rayed. However, there are guidelines that do not recognize this red flag, X-rays should be performed only where there are red flags, or where the pain is chronic.”
3. **Cervical spine**: “Prior to any manipulation of the cervical spine, X-rays must be taken, regardless of the duration of the patient’s pain history.” and “This guideline applies even if the patient’s condition is not chronic.”\(^56\)

Previously, the French National Agency for Accreditation and Evaluation in Health (ANAES)\(^57\), in its guidelines for the use of imaging techniques in low-back pain cases, stated that “outside the context of looking for evidence of symptomatic low-back pain, the use of imaging techniques is not indicated in the first seven weeks of the low-back pain, **unless the envisaged therapeutic modalities (such as manipulation or infiltration) make it necessary formally to exclude any specific form of low-back pain.**”\(^57\) (emphasis is ours).

**Council on Chiropractic Practice Clinical Practice Guidelines (CCP)**\(^58\)

In the year 1998 and 2003, the CCP\(^58\) adopted a radiology guideline for Chiropractic Practice. This guideline included the reliability and utility of chiropractic radiography use for spinal subluxation. However, this guideline was not a comprehensive review of the individual radiographic views as used by practicing chiropractors. It brought forth preliminary reliability, validity and clinical outcome studies in terms of chiropractors’ radiological assessment of subluxation. The current PCCRP guidelines have utilized this CCP\(^58\) document as a preliminary work to build upon. We list the CCP guideline’s relevant plain film radiography and Videoflouroscopy statements here:

1. **Plain Film Radiography is indicated to provide:**
   - “...information concerning the structural integrity of the spine, skull and pelvis;
   - “The misalignment component of the vertebral subluxation”;
   - “The foraminal alteration component of the vertebral subluxation”;
   - “The postural status of the spinal column”;
   - “Imaging procedures, including post-adjustment radiography, should be performed only when clinically necessary”;
   - Concerning radiographic line drawing procedures, “These procedures may be done by hand, or the chiropractor may utilize computerized radiographic digitization procedures.”\(^58\)

2. **Videoflouroscopy (VF):**
   - VF “may be employed to provide motion views of the spine when abnormal motion patterns are clinically suspected.”
   - VF “may be valuable in detecting and characterizing spinal kinesiopathology associated with vertebral subluxation.”
   - “Observational and case studies support the use of Videoflouroscopy to evaluate vertebral motion when this information cannot be obtained by other means.”\(^58\)

**International Chiropractors Association (ICA)**\(^59\)

In the year 2000, the ICA adopted a radiology guideline for Chiropractic Practice. This guideline was a preliminary report attempting to document the reliability and utility of chiropractic radiography use for spinal subluxation. However, this guideline was incomplete in the radiographic views it listed, in the reliability and validity discussion, in the clinical utility
discussion and in the review of the available chiropractic literature in general. The current
PCCRP guidelines have utilized this ICA document as a preliminary work to build upon. We list
the ICA 2000 relevant plain film radiography and Videoflouroscopy statements here:

A. Plain Film Radiography

1. “To provide information concerning the hard tissue components of the spine, skull
and pelvis, or other skeletal structure.
2. To provide information concerning the misalignment component of the vertebral
subluxation, or other articulation.
3. To provide information concerning the foraminal alteration component of the
vertebral subluxation.
4. To provide information concerning the dynamics of spinal motion.
5. To provide information concerning abnormal spinal contours.
6. To detect anomalous structures that may contribute to spinal distortions, sacral
plateau abnormalities, etc.”
7. Postural studies: views may be obtained in various postural positions as clinically
required. It is acknowledged and accepted that this may result in more than one view per
projection with posture being the variable.
8. Repeat studies: Due to the dangers inherent in radiation exposure, repeat studies
should only be used as clinically required.
9. Plain film radiography may be employed when clinical data indicates the likely
presence of a condition which may affect patient care. This includes biomechanical
assessment...

B. Videoflouroscopy (VF) Indications:
1. “Flexion-extension injuries,
2. Direct injury,
3. Postoperative evaluation,
4. Assessment of Hypermobility associated with subluxation when such information cannot
be obtained by other more cost-effective means,
5. Suspected ligamentous instability,
6. Presumed radicular compression,
7. Spinal stenosis,
8. Scoliosis, structural and functional curvature evaluation,
9. Videoflouroscopy should be used as an adjunctive procedure to plain film studies, and
not as a replacement for those studies.”

PCCRP Discussion of Previous Guidelines

In the above summaries, we have presented a comprehensive review of 13
groups/organizations guideline position statements regarding spinal radiography. These different
guidelines provide an international feel for the current trend regarding spinal radiography
utilization in spinal related conditions. Most of the non-chiropractic driven guidelines deal
exclusively with acute low back pain only, a few discuss chronic low back pain, 3 discuss
thoracic disorders, and a few detail cervical spine disorders. Interestingly, the lack of evidence
on a specific condition and the type of evidence on a specific topic that a given organization
reviews creates considerable variability and gives rise to different view points and recommendations.

The ACR guidelines are the most comprehensive detailing all regions of the spine and pain conditions. The majority of the guidelines reviewed above are not specific to the type of treatment interventions (spinal adjustments) that Chiropractic Clinicians provide; there are three exceptions (SOFMMOO, CCP, ICA). The majority of the guidelines related to ‘diagnostic radiology’ do not consider the difference in the Chiropractic Clinician’s use of spinal radiology; which is to identify, quantify, and develop treatment strategies for the 6 types of structural subluxations detailed in Section V.

Of interest, the 3 organization’s guideline recommendations that consider manual therapy and the chiropractic adjustment, are somewhat different than the rest of the guidelines (except for the ACR’s). Based on this information, it is the current PCCRP’s position that subluxation analysis using spinal radiographs and the treatment approaches that relate to it, is a specialty that requires different spinal radiography guidelines for the practicing Chiropractic Clinicians utilizing this approach.

The PCCRP guidelines put forth in Section II of this document have built upon the two previous guidelines developed and recommended by the two organizations (CCP, ICA) specifically addressing spinal subluxation analysis via radiography. We believe the current PCCRP guidelines to be a significant improvement over these two previous guidelines in as much as it is more comprehensive and details the reliability, validity, clinical outcomes, and clinical utility of each separated spinal radiographic view that a Chiropractic Clinician might ascertain.

Summary

Through some publications in the literature and the consequent use of these publications by MCO’s in their guidelines (ACN, ASHN, etc…), a subgroup of publishing DACBR’s and chiropractic academics are attempting to restrict the clinical use of radiography in chiropractic practice. This attempt by this subgroup of publishing DACBR’s and the MCO’s (ACN, ASHN) is in direct opposition to the official radiological guidelines of the ACCR (i.e., the DACBR’s own professional organization), which states that x-rays are to be used “…as determined by, the treating chiropractic physician.” Furthermore, this attempt to limit chiropractic clinician’s x-ray privileges is in direct contrast to other health care groups with radiological privileges (AAFP, AMA, AAOS, ACR, and SOFMMOO). Lastly, most of the guidelines presented in this document are based on ‘diagnostic radiology’ which disregards the difference in treatment provided by Chiropractic Clinicians who definitively use the x-ray to determine patient treatment interventions and safety of such interventions; and this information cannot be ascertained by means other than radiography (see Sections IV, V, and X for evidence).
References

VII. Radiation Safety: LNT Model versus the Radiation Hormesis Model

**RECOMMENDATION**

Radiography is a safe procedure. The ionizing radiation levels associated with spinal radiography is in the range associated with possible health benefits, termed Radiation Hormesis. Spinal radiography dose levels are in the low range where, health risk estimation can only be ‘qualitative accentuating a range of hypothetical health outcomes with an emphasis on the likely possibility of zero adverse health effects.’ The PCCRP panel concludes that the benefits of subluxation assessment and consequent treatment guidance that spinal radiographs provide outweighs the perceived and known health risks.

**Supporting Evidence:** Population Studies Class 1-4, Basic Science, and Validity.

**PCCRP Evidence Grade:** Population, Basic Science, and Validity Studies = a.

**Introduction**

The purpose of this section is to elaborate a realistic understanding of the risks of medical/chiropractic x-rays for the general public. There are two models of radiation effects on organisms: Linear No-Threshold (LNT) model and the Radiation Hormesis model. Using the huge exposures during the atomic bombing of Japan in the 1940’s, the LNT model was derived by drawing a straight line down to zero exposure and claiming all radiation exposure causes a cancer risk. The LNT model continues to be used to estimate cancer risks from low doses of radiation, such as medical x-rays, without any conclusive supporting data. Proponents of the LNT model seem to omit Radiation Hormesis information from their commentaries, review articles, and government documents. Though many of the world’s experts on this subject matter seem to be more in favor of the Radiation Hormesis model, the LNT model continues to be discussed in hopes of better quality research which will allow scientists to logically refute it. Before this time, the LNT model continues to be considered as a means of exercising a more rigorous radiation safety precaution.

There exists extremely strong evidence that Radiation Hormesis (health benefit) occurs in plants, microorganisms, invertebrates, and experimental animals. In fact, it was proven with statistically significant results from countless studies that benefits from low levels of radiation improved physiologic function from immunity and reproduction to growth and longevity. Ironically, much of this research came from studies evaluating ‘risks’ from radiation – so author bias is unlikely.

In this section, we will review both the LNT model and the Radiation Hormesis model and suggest that the health benefit from a screening protocol in medical/chiropractic x-rays likely outweighs any risk. According to some of the credible x-ray research out there, it is even possible there are actually health benefits from small amounts of x-ray exposure.

**Simplifying the Units of Radiation Exposure**

There are several quantities/units used in articles on radiation doses. Some of these are abbreviated as Gy, rad, Sv, and rem. Most doctors in English speaking countries are familiar with the rad and rem abbreviations. This is because these are derived from the “English” system, of measuring units, such as the inch, the foot, the yard, etc. Most of the countries of our world
have agreed to use the International System of Units (SI). This is where the abbreviations of Gy and Sv are defined.

The unit of absorbed dose is the gray. One gray is defined as one joule of energy absorbed per kilogram of matter. This unit converts to the rad by:

\[1 \text{ Gy} = 100 \text{ rad} = 1 \text{ J/kg}.\]

The unit of dose equivalent is the sievert. The sievert is the product of the absorbed dose and the quality factor for the irradiating beam. This sievert unit converts to the rem by:

\[1 \text{ Sv} = 100 \text{ rem}.\]

To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation. For Medical X-rays, generally it is assumed that \( Q = 1 \). However, the actual dose to different parts of the body from an X-ray procedure varies because different tissues and organs have varying sensitivity to radiation exposure. The term effective dose is used when referring to the dose averaged over the entire body. The effective dose accounts for the relative sensitivities of the different tissues exposed. Additionally, it allows for quantification of risk and comparison to more familiar sources of exposure that range from natural background radiation to radiographic medical procedures.

It is important to note that radiation exposure comes from the natural environment (the sun’s rays and radon gas from the ground found at some level in most homes), industrial processes, and healthcare processes.

The US Environmental Protection Agency has a great annual dose calculator online (http://www.epa.gov/radiation/students/calculate.html). It should be noted that average annual radiation exposure is much higher in Denver Colorado than in the state of New Jersey. Looking at health statistics, people in Denver have on average, much better health than people in New Jersey. The National Council on Radiation Protection and Measurements (NCRP) is a federal organization who meets every 5 years to review health factors in ionizing radiation. The guidelines for radiation they establish are the gold standard in radiation exposure for the United States. These standards are often adopted by the International Council on Radiation Protection and Measurements (ICRP). It is important to note that in their most recent report, on page 97, the NCRP states the safe range of annual industrial exposure for workers is 5rem (or 5000mrem). This will be important information for discussion in the remainder of this section.

### Natural Background Radiation

We are exposed to radiation from natural sources every day. The average person in the U.S. receives an effective dose of approximately 300 mrem per year from naturally occurring radioactive materials and cosmic radiation from outer space. These natural "background" doses vary throughout the country. According to the United States EPA, influential factors can be from geographical elevation, geographical region, food, water and air ingestion, pacemakers, crowns in dental work, miles traveled on airplanes, time spent in airport security, gas lantern mantles used when camping, living in a concrete building, wearing a luminous wristwatch, watching television, using a computer, having a home smoke detector, living within 50 miles of a coal fired power plant and more! It is interesting that according to the EPA, nuclear power plants expose the public to less radiation than coal fired power plants do. The added dose from cosmic rays during a coast-to-coast round trip flight in a commercial airplane is about 3000 mrem. Altitude plays a big role. A large source of background radiation comes from radon gas in our homes; about 200 mrem per year. Like other sources of background radiation, exposure to radon varies widely from one part of the country to another.
The following Table 1 was developed by the National Council on Radiation Protection and Measurement (NCRP 93) and is a breakdown of the sources of radiation for the population of the United States. These numbers are averages and were obtained by estimating the total dose for the US, and dividing by the number of people in the US.

Table 1. Annual Effective Dose Equivalent

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DOSE (mrem/yr)</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon</td>
<td>200</td>
<td>55%</td>
</tr>
<tr>
<td>Cosmic</td>
<td>27</td>
<td>8%</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>28</td>
<td>8%</td>
</tr>
<tr>
<td>Internal</td>
<td>39</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Total Natural:</strong></td>
<td><strong>300</strong></td>
<td><strong>82%</strong></td>
</tr>
<tr>
<td>Artificial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical X ray</td>
<td>39</td>
<td>11%</td>
</tr>
<tr>
<td>Nuclear medicine</td>
<td>14</td>
<td>4%</td>
</tr>
<tr>
<td>Consumer products</td>
<td>10</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total Artificial:</strong></td>
<td><strong>63</strong></td>
<td><strong>18%</strong></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational</td>
<td>0.9</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Nuclear Fuel Cycle</td>
<td>&lt;1</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Fallout</td>
<td>&lt;1</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>&lt;1</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td><strong>Total Artificial and Natural:</strong></td>
<td><strong>360</strong></td>
<td></td>
</tr>
</tbody>
</table>


Of importance to the current PCCRP Guideline section, in 2006, the American population was exposed to approximately seven times as much ionizing radiation from medical procedures as compared to data from the early 1980s. The 2006 data indicates that medical exposure accounts for slightly less than 50% of the total radiation exposure of the U.S. population from all sources. See Figure 1A.

However, it is important to emphasize that plain film radiography (including fluoroscopy) only accounts for 5% of the total radiation exposure to the U.S. population. The major reason for the increase in radiation exposure from medical procedures is due to a large increase in the utilization of computed tomography (CT) imaging and nuclear medicine. See Figure 1A.

In 2006, background radiation contributed about half of the total annual exposure. Other small contributors of exposure to the U.S. population included consumer products and activities, industrial and research uses and occupational tasks. See Figure 1A. The Physics department at Idaho State University presented similar findings based, in part, on the NCRP report 93. See Figure 1B.
**Figure 1AB.** Sources of radiation and their estimated percentages for the population of the United States. In A, a pie chart from the National Council on Radiation Protection and Measurement (NCRP 93) Report No. 160, "Ionizing Radiation Exposure of the Population of the United States". In B, data from the Physics department at Idaho State University.
How Can We Judge Safe X-Ray Exposures?

Some Common Radiographic Exposures

Many common radiological examinations expose the individual to very small doses of radiation. Tables 2-4 below show a number of common, adult low dose radiological examinations from different sources.\textsuperscript{21,22,88,91,122} These values are estimates and range from the lower end of the spectrum to the high end of dosage for each view. Keep in mind that these numbers are not representative of every x-ray machine but reflect typical exposure according to actual measurements made annually by NJ x-ray physicists. There is no calculation to accurately predict mRem in exposure for these x-rays because it is situation specific. The calculation must be specific to the specific machine used as well as the air in the room, shielding, size of the person, grid, cassette, screen and film as well as processor traits.\textsuperscript{88,122}

Note that 1 mrem is approximately equal to 1 day of exposure to natural background radiation; the time should be rounded to the nearest day, week or month (e.g. 25 mrem is about 1 month).

Table 2. Some common, adult low dose radiological examinations and effective dose.\textsuperscript{21,22,91}

<table>
<thead>
<tr>
<th>Diagnostic x-ray exam</th>
<th>Description</th>
<th>Effective dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremity radiograph</td>
<td>Any extremity (elbow, forearm, knee, ankle)</td>
<td>&lt; 1 mrem</td>
</tr>
<tr>
<td>Chest x-rays</td>
<td>AP</td>
<td>10 mrem</td>
</tr>
<tr>
<td>Mammogram</td>
<td>Two views of each breast (four films)</td>
<td>20 mrem</td>
</tr>
<tr>
<td>Skull (AP view)</td>
<td>Single film</td>
<td>10 mrem</td>
</tr>
<tr>
<td>Skull (Lateral view)</td>
<td>Single film</td>
<td>5 mrem</td>
</tr>
<tr>
<td>Abdomen (AP view)</td>
<td>Single film</td>
<td>30 mrem</td>
</tr>
<tr>
<td>Dental x-ray</td>
<td>Single film</td>
<td>10 mrem</td>
</tr>
<tr>
<td>CT Scan</td>
<td>Body</td>
<td>10 mSv =1000 mrem</td>
</tr>
<tr>
<td>Cervical spine x-rays</td>
<td>AP &amp; Lateral</td>
<td>44 mrem</td>
</tr>
<tr>
<td>Lumbar spine x-rays</td>
<td>AP &amp; Lateral</td>
<td>130 mrem</td>
</tr>
</tbody>
</table>

Equivalent Exposures

| Pilot: NY-Athens | Trip Dose | 420 mrem |
| Pilot: Chicago-SF | Trip Dose | 280 mrem |

| Fat person: Pie-a-la-mode | Equivalent in life expectancy reduction | 35 mrem |

We note that from Table 2 above:

1. \(1,000 \text{mrem} \approx 22.7 \text{ Cervical series (1,000/44)} \) or \( \approx 7.7 \text{ Lumbar series (1,000/130)} \).

Remember, according to the EPA, a reasonable environmental radiation exposure per year might be something like 350 mrem (.35 rem).\textsuperscript{123} According to NCRP Report 102, the safe annual dose for industrial exposure is 5 rem or 5000 mrem.\textsuperscript{88}

The state of NJ Department of Environmental Protection, Bureau of Radiologic Health works with the federal government and keeps statistics on all diagnostic x-ray equipment used in New Jersey.\textsuperscript{122} Because there is quite a bit of variation between different x-ray machine designs, different methods of image capturing, varying image processing between machines from different manufacturers in different years of production, using somewhat different technologies to yield a diagnostic x-ray, the calculation of radiation exposure to the patient for each x-ray...
taken becomes very complex. Still, in this state, every diagnostic machine is required to maintain an ongoing quality control program to minimize excess radiation to healthcare patients as well as to healthcare employees. For each machine, the Bureau of Radiologic Health in the state measures patient exposure rates for a variety of common x-rays taken. They have standardized diagnostic exposure ranges for only 3 of the common x-ray views.122

Table 3. Standardized diagnostic exposures from the Bureau of Radiologic Health

<table>
<thead>
<tr>
<th>View</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest:</td>
<td>5 mRem</td>
<td>20 mRem</td>
</tr>
<tr>
<td>A-P Lumbar:</td>
<td>100 mRem</td>
<td>450 mRem</td>
</tr>
<tr>
<td>Foot:</td>
<td>5 mrem</td>
<td>30 mRem</td>
</tr>
</tbody>
</table>

Based on the numbers presented in Table 3, the Bureau of Radiologic Health was able to extrapolate the likely data for exposures of common chiropractic x-rays presented in Table 4.

Table 4. Extrapolated From Measured Exposure From State of NJ Diagnostic X-Ray: 88,122

<table>
<thead>
<tr>
<th>View</th>
<th>SID</th>
<th>Pt. Size</th>
<th>KvP</th>
<th>mAs</th>
<th>ESE</th>
<th>% Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Lower Cervical</td>
<td>40”</td>
<td>15 cm</td>
<td>78</td>
<td>20</td>
<td>58 mRem</td>
<td>1.16%</td>
</tr>
<tr>
<td>APOM</td>
<td>40”</td>
<td>12 cm</td>
<td>72</td>
<td>20</td>
<td>46 mRem</td>
<td>0.92%</td>
</tr>
<tr>
<td>Lateral Cervical</td>
<td>40”</td>
<td>10 cm</td>
<td>70</td>
<td>20</td>
<td>42 mRem</td>
<td>0.84%</td>
</tr>
<tr>
<td>AP Thoracic</td>
<td>40”</td>
<td>23 cm</td>
<td>78</td>
<td>80</td>
<td>280 mRem</td>
<td>5.60%</td>
</tr>
<tr>
<td>Lateral Thoracic</td>
<td>40”</td>
<td>30 cm</td>
<td>85</td>
<td>80</td>
<td>401 mRem</td>
<td>8.02%</td>
</tr>
<tr>
<td>AP Lumbar</td>
<td>40”</td>
<td>23 cm</td>
<td>78</td>
<td>100</td>
<td>350 mRem</td>
<td>7.00%</td>
</tr>
<tr>
<td>Lateral Lumbar</td>
<td>40”</td>
<td>30 cm</td>
<td>90</td>
<td>200</td>
<td>1123 mRem</td>
<td>22.46%</td>
</tr>
</tbody>
</table>

Percentage of the US Government Annual Industrial Worker Safe Limit of 5 Rem

Based on the above extrapolated data in Table 4, it is likely that one chiropractic x-ray series consisting of 2 cervical x-rays (100 mrem), 2 thoracic x-rays (681 mrem) and 2 lumbar x-rays (1473 mrem) would comprise up to about 2200 mrem. This is less than half of the 5000 mrem deemed as safe annual industrial exposure and does not factor in other radiation. There is no known research to show this level of radiation produces more of a risk than the danger of not discovering an asymptomatic fracture, infection, congenital defect, or subluxation for that matter, during routine periodic chiropractic screenings. It should be noted that the US EPA designates one medical x-ray as having an average exposure of 40 mrem. 123

The Health Physics Society is a nonprofit scientific professional organization whose mission is to promote the practice of radiation safety. Since its formation in 1956, the Society has grown to approximately 6,000 scientists, physicians, engineers, lawyers, and other professionals representing academia, industry, government, national laboratories, the Department of Defense, and other organizations. (www.hps.org) The Health Physics Society released a position statement on Radiation Risk on March, 1996. It stated: “In accordance with current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risk below an individual dose of 5 rem = 5000 mrem in one year, or a
lifetime dose of 10 rem in addition to background radiation. [According to the US Department of Environmental protection, 5rem of exposure is equivalent to 125 medical x-rays.] Risk estimation in this dose range should be strictly qualitative accentuating a range of hypothetical health outcomes with an emphasis on the likely possibility of zero adverse health effects. The current philosophy of radiation protection is based on the assumption that any radiation dose, no matter how small, may result in human health effects, such as cancer and hereditary genetic damage. There is substantial and convincing scientific evidence for health risks at high dose. Below 10 rem [10,000 mrem] (which includes occupational and environmental exposures) risks of health effects are either too small to be observed or are non-existent.

A. The LNT Model of Radiation Exposure

The Linear No-Threshold model is the predictive model used by all regulatory agencies to measure risks from ‘toxic’ agents including ionizing radiation. This model predicts cancer rates and deaths from a linear extrapolation from high exposure atomic bomb data. It assumes that any exposure to radiation above zero-dose linearly increases your risks of radiation sickness, cancer, or death from any exposure.

There was and still is data above an exposure to radiation of 0.2 Sv = 20 rem = 20,000 mrems to support this linear extrapolation. However, until circa 1970 there was no data from human and animal exposures to radiation in the so-called “Low Dose range”, which is in the interval of 0 to 20,000 mrems. Therefore, predictions (assumptions) as to radiation sickness, cancer, or death from any exposure between 0 and 20,000 mrems were routinely made from 1945 to 1970 from the LNT model in the absence of data, and sadly, assumptions as to radiation risks are still made from the LNT model in the Low Dose Range today (see BIER 2005 Report and Berrington de Gonzalez et al 2004 study).

However, starting in the late 1960s and continuing to the present time, many experiments, data, and reports were conducted with humans and animals in the exposure range of 0-20,000 mrems (Low Dose Range). These data suggested a new model of radiation exposure termed the ‘Hormesis Model’. The LNT Model and the Hormesis Model are nearly identical in the range above 20,000 mrems (See Figure 2).

![Graph showing the LNT Model and Hormesis Model](image-url)
It is quite frustrating that still today many use the LNT model to predict radiation sickness, cancers, and deaths from any exposure between 0 and 20,000 mrems (Low Dose). While such agencies as the Heath Physics Society (www.hps.org), the French Academy of Sciences,1,85,113 and the US Environmental Protection Agency123 have stated that the evidence in the Low Dose region indicates a zero risk and a possible benefit, others ignore the evidence in the Low Dose region and still vehemently oppose even medical x-rays, which have exposures in this range (Bussieres et al 2006).6 While in Chiropractic journals Oakley et al (2005, 2006)91-93 have presented data for the benefits of plain film radiography, data in the Low Dose range in review articles, and critiqued Bussieres et al (2006),6 there is still no change in some views that strongly oppose the routine use of radiography in chiropractic practice. See Figure 3.

**Figure 2.** The LNT Model and the Hormesis Model are nearly identical **EXCEPT** at Low Doses. Until recently (40 years) there was no data in the low dose region, so the LNT Model was “assumed”. Figure 3 enlarges the Low Dose Region (0-20,000 mrems).

**Figure 3.** ‘Linear’ indicates the LNT model, a linear extrapolation from zero to high dose-rate. The greater the exposure, the linear increase in cancer risk. ‘Hormesis’ indicates the U-shaped pattern, where between zero and the zero equivalent point (ZEP) there is less risk of cancer, however, doses greater than the ZEP indicate a near linear increased risk of cancer with increasing doses. (Adapted from Luckey, 1991.73).

### B. Historical Perspective

It should be known that immediately after the discovery of x-rays along with research, therapeutic treatments using radiation was widespread. In fact, there was an explosion of radiation therapies within medicine. These included treatment of back pain in patients with ankylosing spondylitis (AS),5 treatment of benign skin conditions including children with ringworm on the scalp,5 and even treatment of sterility.59-61 In 1962, ‘consumptive’ children were treated with stimulatory radiation doses in Europe.73 The treatment of arthritis, mastitis, erysipelas, abscesses, and carbuncles consisted of 2-8 treatments with 0.3-1.5Gy (approximately up to 150,000 mrem), with apparent cure rates of 2-95%.73 In fact, before the discovery of
antibiotics, countless minor diseases were treated by radiation therapy.\textsuperscript{119} Non-medical radiation therapy was also very common including removal of facial hair in ‘beauty clinics’ and even radium-containing drinks served at ‘health spas,’ and fluoroscopy in shoe-fitting.\textsuperscript{5} There was no legal control of who could use or not use x-ray machines in most countries.\textsuperscript{5}

Although detrimental biological effects resulting from x-rays appeared in the literature as early as 1896,\textsuperscript{36,81,86} it was not until the 1920’s when the first radiation protection limits were set.\textsuperscript{62} In fact, throughout recent history the adoption of the LNT took place, in part for simplicity as well as the nuclear arms race threat. In the 1995 American Academy of Health Physics Radiology Centennial Hartman Oration, Kathren notes:

After World War II, the pathway takes a significant turn away from the tolerance dose directly towards the linear non-threshold dose-response model and becomes more of a two lane highway than the leisurely pleasant and relaxed country lane it once had been.

In the late 1940’s, scientific interest in the applicability of the linear non-threshold model for somatic effects was kindled, and the model to be applied in radiation protection risk assessment methodology. Usage was gradually refined over a period of perhaps 15 or 20 years with special reference to the potential long term health effects from atmospheric nuclear weapons testing. Regrettably, political or ideological considerations were not absent in the choice and refinement of the low dose-risk assessment model for this and other purposes, and sometimes took precedence over strictly scientific considerations (emphasis ours).\textsuperscript{62}

The original report from the United Nations Scientific Committee on the Effects of Radiation (UNSCEAR, 1958)\textsuperscript{117} specifically states “present knowledge concerning long-term effects and their correlation with the amount of radiation received does not permit us to evaluate with any precision the possible consequence to man of exposure to low radiation levels.” This fact remains today.\textsuperscript{7,62} The report also states: “Many effects...cannot be distinguished from effects of other agents; many will only develop once a threshold dose has been exceeded some may be cumulative and others not...the possibility cannot be excluded that our present estimates exaggerate the hazards of chronic exposure to low levels of radiation.” Thus, there are several potential critical flaws to use of the LNT admitted in this report.

Despite the potential downfalls of using the LNT for radiation risk assessment, the following year the ICRP adopted this model. Ever since the 1950s, all official groups (i.e. UNSCEAR, ICRP, NCRP, and US National Academy of Sciences committees) have consistently used the LNT dose response model to estimate the risks of cancer induction from low-level radiation.\textsuperscript{16}

Even if a report correctly interprets radiation data showing incongruence with LNT expectations (or even health benefits as the Hormesis model implies) from low-level radiation (i.e. levels many times above current ‘safe’ standards), it is never apart of its’ conclusions and recommendations. The BEIR V (1990) report, for example, states “studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural radiation, have not shown consistent or conclusive evidence of an association increase in the risk of cancer.”

To this day, including the most recent BEIR VII document (supporting LNT), little has changed in risk assessment. The LNT continues to prevail as the, ‘gold standard’, despite an incredible amount of evidence for the hormeric model or even the threshold model. This is done in spite of lack of strong evidence to support the LNT model simply because the LNT is a more
exposure conservative model and final conclusive research simply has not been done at this time. In our opinion the LNT is a model of worst case scenario but by no means holds accuracy for actual health effects of low dose radiation exposure.

It is interesting to note the unanimous report by the French Academy of Sciences and National Academy of Medicine (2005)\textsuperscript{1,85,113} states:

\textit{“In conclusion, this report doubts the validity of using the LNT in the evaluation of the carcinogenic risk of low doses (<10,000 mrem) and even more for very low doses (<1000 mrem). ...the use of LNT in the low dose or dose rate range is not consistent with the current radiobiological knowledge; LNT cannot be used without challenge...for very low doses (<1000 mrem).... The eventual risks in the dose range of radiological examinations (10 to 500 mrem, up to 2000 mrem for some examinations) must be estimated taking into account radiobiological and experimental data. An empirical relationship which is valid for doses higher than 20,000 mrem may lead to an overestimation of risk associated with doses one hundredfold lower and this overestimation could discourage patients from undergoing useful examinations and introduce a bias in radioprotection measures against very low doses (<1000 mrem).”}\textsuperscript{1,113}

C. Hormesis

Hormesis is the stimulatory effect of an agent at low exposure levels that is harmful at higher exposure levels. Radiation hormesis is the term used when this phenomenon results from radiation exposure.

Radiation hormesis is not new, it was first discovered by Professor W. Shrader over a century ago.\textsuperscript{109} Shrader found that guinea pigs being exposed to x-rays prior to being inoculated with the diphtheria bacillus actually lived while an unexposed comparison group died within 24 hours.\textsuperscript{109} Other medical research with radiation, outside the chiropractic profession, was being performed until about 1945 when the financial support shifted to studies evaluating harm from excess radiation.\textsuperscript{74}

The chiropractic profession, however, continued to study subluxation detection by use of x-ray. In fact, by this time several techniques (and their x-ray analyses) were developed and many were to come.

A renewed interest into the stimulatory effects of radiation began in 1981, with the publication of the book by T.D. Luckey, titled ‘Hormesis with Ionizing Radiation.’\textsuperscript{75} This book, having 1200 references, validated radiation hormesis.\textsuperscript{75} It was determined that there existed incontrovertible evidence that radiation hormesis occurs in microorganisms, plants, invertebrates, and experimental animals.\textsuperscript{75} In fact, it was proven with statistically significant results from countless studies that benefits to low levels of radiation improved physiologic function from immunity and reproduction to growth and longevity. Ironically, much of this research came from studies evaluating ‘risks’ from radiation. Luckey is a controversial figure in the ionizing radiation world. One of the reasons for his controversial status is that no one has been able to disprove his theories and observations on hormesis.

Since that 1980 book by Luckey,\textsuperscript{75} he and several others have reviewed radiation hormesis.\textsuperscript{10,11,15,16,39,52,53,58,64,66,73,75,76,77,87,91,93,94-99,101,102,113} The message is similar in all these reviews; that is, the LNT is invalid for estimating radiation risks from low dose exposures, and that these low dose exposures can improve physiologic function and health. In fact, it has been stated that 98% of the data in the low-dose region supports the hormesis concept.\textsuperscript{53}
Hiserodt sums up the ‘hormesis/LNT controversy nicely: “Those who advocate the Linear No-Threshold theory base their belief on the extrapolation of high-level exposure responses down to low levels. But when low-level data are available, they almost always show a bio-positive-or stimulatory-response.” This should not be a surprise given the dose response relationships from chemicals, pharmaceuticals, and physical agents, including ionizing radiation, “the hormetic model is not an exception to the rule – it is the rule.”

“The evidence is incontrovertible. It is not challenged. It is ignored for whatever reason: ignorance, ideology, or indolence.” Luckey lists the main reasons why most epidemiologists and government agencies neglect the hormetic phenomenon apparent in most data that includes low doses:

1. Assume all radiation is harmful;
2. Include data from low-dose participants in their control cohort;
3. Have no low-dose groups in the protocol;
4. Do not use available low-dose data;
5. Do not report enough raw data to construct a dose-response curve at low doses;
6. Use a one-dimensional formula or statistic which does not allow expression of beneficial effects;
7. Ignore data that does not fit the LNT dose-response curve;
8. Distort results by the use of median instead of mean or average value;
9. Interpolate between high doses and background levels to obtain fancied results to produce and support unreasonable regulations;
10. Assume cell functions are not subject to whole body activities;
11. Ignore increased immune competence found in exposed organisms; and
12. Ignore increased health and average lifespan while emphasizing risks and death.

D. Human Evidence of Radiation Hormesis and Invalidation of the LNT

When reading the next few pages, it is important for the reader to keep in mind that there are a certain number of cancers and cancer deaths in the general population. Thus, whenever, a causation of a certain number of cancers is claimed, it must be compared to the percentage of such cancers in the general population, i.e., be above what is found in the general population.

The most important data for assessing risks of radiation exposures to humans began with the Japanese atomic bomb studies. Today, 60 years of follow-up data has been examined and reveals a very fascinating trend. Bomb survivors are outliving their unexposed peers in fact, exposures of up to 70rem (i.e. 70,000mrem) shows a death rate that is lower than the unexposed comparison population. Hiserodt noted that this Japanese data is from 40 years after the bomb and well after the established latency time for supposed cancer onset from the radiation. In numerical terms, for every 10,000 persons exposed to 1-1.9 cGy (1,000-1,900mrem) there were 50 fewer definitively diagnosed cancer deaths and 3 fewer leukemia deaths than in unexposed controls.

Since the discovery of x-rays, those involved in taking images from patients have been exposed to decreasing exposures over the decades. Data from British radiologists have been studied over a 100-year period. It was determined that after 1920, British radiologists had lower cancer mortality than the average for the whole population of England and Wales. After 1954, radiologists had 29% lower standardized mortality ratio (SMR) from cancer, 32% lower SMR.
from all causes, and 36% lower SMR from non-cancer causes as compared to non-radiologists medical doctors. This data also invalidates the LNT. 11

Prior to the antibiotic era, treatment for tuberculosis (TB) consisted of x-ray doses to the chest. Therefore, there was great concern about the possibility that examination and treatment may induce breast cancer in those with TB. The Canadian fluoroscopy study 24,82 showed that among 31,710 females treated between the years 1930-1952, those females exposed to cumulative exposures ranging from 10-29cGy (i.e. 10,000-29,000mrem) had significantly lower than average rates of breast cancer. The hormetic pattern to the data 53 demonstrates that if a million women were to receive a dose of 15cGy, it would relate to 7,000 fewer deaths from breast cancer. 101

The ‘Nuclear Shipyard Workers Study’ 80 (NSWS) was published in 1991, took place from 1980-1988, and cost $10 million dollars to perform by the School of Public Health at John Hopkins University, under contract of the US Department of Energy. It is the only study on radiation workers that has age-matched and job-matched control groups.11 Three groups were included: 27,872 ‘exposed’ workers (>500mrem), 10,348 ‘minimally exposed’ workers (<500mrem), and 32,510 ‘unexposed’ controls (0rem). The ‘exposed’ workers death rate from cancer and all causes was four, and 16 standard deviations lower than the controls. “The probability of such a very low death rate from all causes being accidental is less than one in 10 million billion.” 11

In Taiwan, during the 1980s, there were more than 180 buildings constructed with recycled steel contaminated with cobalt-60. 69 About 10,000 people were affected and lived in these buildings for 9-20 years. The average exposure was 0.4Sv (i.e. 40,000mrem). The average cancer death rate in Taiwan over this 10-year period was 116 vs. 3.5 persons per 100,000 person years for the affected residents.15 Chen et al.15 stated that because many of the confounding factors apparent in other studies (i.e. A-bomb and Chernobyl studies) are not present in this data; they suggest that their data “should be one of the most important events on which to base radiation-protection standards.” They conclude that a “dose rate of the order of 50mSv per year (5,000 mrem) greatly reduces cancer mortality, which is a major cause of death in North America.”15

Radon gas inhalation, within the home, is feared to be a major contributor to lung cancer. After studying the effects of radon exposure to incidence of lung cancer for 90% of the US population, B.L. Cohen discovered that those residing in homes with greater radon levels had 40% lower mortality rate from radon-induced lung cancer.17 The data has been rigorously evaluated to eliminate more than 500 potential confounding factors.18,19 Radon exposure from health spas in Japan also demonstrate those exposed to radon have significantly lower cancer-induced mortality ratios than not exposed.66,101

Cancer rates for those exposed to radium has been investigated in ‘radium dial painters’ and others occupationally exposed.37,38 Those exposed to less than 1000cGy did not develop any cancers. A definite threshold phenomenon was demonstrated - invalidating the LNT. Studies of workers exposed to inhalation of Plutonium have demonstrated hormesis; that is, these workers have lower lung cancer mortality rates than controls.33,46,118

Natural background radiation vs. cancer mortality rate studies have demonstrated those living at higher altitudes (and getting greater natural background radiation exposures) have significantly less cancer mortality rates than those living in lower altitude states.35,57 In some countries exposure is greater along the coast. For example, a comprehensive survey of an Indian population exposed to high-level natural background radiation was reported by Nair et al.90
Approximately 25% (100,000 people) of the total population lived in areas with high natural radiation from the thorium deposits along coastal areas. In these regions, the environmental exposures are as high as 70 mGy/year and 7.5 times the level seen in interior areas. Using portable scintillometers, radiation levels in and outside more than 66,306 houses were measured. Confounding variables such as lifestyle, socio-demographic features, occupation, housing, residence history, tobacco and alcohol were obtained and analyzed. Nair et al. found no evidence that cancer occurrence is consistently higher due to increased levels of external gamma-radiation exposure.

E. Cohen’s Outline

The reader has noted that there is much evidence in the previous section that discredits the LNT model. However, there is much more to be learned. In preparation for this section of our document, we contacted one of the leading authorities on radiation exposure risks, Dr. B. L. Cohen, University of Pittsburgh, Pennsylvania, USA. We asked for a more comprehensive analysis of the LNT Model versus Radiation Hormesis. What follows is the outline and information that Dr. Cohen provided to us:

1. Problems with the Basis for the Linear-No-Threshold Theory
2. Direct Experimental Challenges to the Basis for LNT
3. Effects of Low-Level Radiation on Biological Defense Mechanisms
4. Stimulation of the Immune System
5. Cancer Risks vs Dose in Animal Experiments
6. Cancer Risks vs Dose in Human Experiments
   a. Critique of Data Frequently Cited Supportive of LNT
   b. Data Contradictory to LNT

E1. Problems with the Basis for LNT

The LNT model is theoretical and simple: A single particle of radiation hitting a single DNA molecule in a single cell nucleus of the human body can initiate cancer. Therefore cancer initiation probability is proportional to the number of events, which is proportional to the number of particles of radiation, which is proportional to the dose. Thus the LNT theory is “the risk is proportional to the dose”. The problem with this simple theory is that other factors affect cancer risk, i.e., human bodies have biological defense mechanisms that prevent the vast majority of radiation events from becoming a cancer.

There are several defense mechanisms: (1) The most important cause of DNA injury is corrosive chemicals termed reactive oxygen species (ROS) and low-level radiation has been shown to stimulate the scavenging processes to eliminate these from cells; (2) There is abundant evidence that low-level radiation stimulates the immune system, while high levels/doses depress the immune response; (3) Radiation can alter cell timing, i.e., the time before the next cell division/mitosis and low-levels of radiation increase this time and allow for more possible DNA repair; (4) Low dose hypersensitivity and increased radiation radioresistance are affected by low-level radiation; and (5) It is now recognized that tissue response, whole organ response, and organism response, rather than just single cellular response, must be considered.

There is another obvious failure of the original LNT model. The theory predicts that the number of initiating events is roughly proportional to the mass of the animal being irradiated.
However, research has shown that the cancer risk for a given radiation field is similar for a 30 gram mouse and a 70,000 gram human.  
Interestingly, validity of the LNT model is based on double strand breaks (DSB) in DNA molecules. However, Feinendegen estimated that ROS causes about 0.1 DSB per cell per day, whereas 100 mSv (10rem) of radiation causes about 4 DSB per cell. Using this information, a 100 mSv dose of radiation would increase the lifetime risk of cancer (28,000 days x 0.1 DSB/day) by only about 0.14% (4/28,000), but the LNT model predicts 7 times that much at 1%

E2. Direct Experimental Challenges to the Basis for LNT

A direct failure of the basis for the LNT model is derived from microarray studies, which determine what genes are up-regulated and what genes are down-regulated by radiation. It was discovered that generally different sets of genes are affected by low-level radiation as compared to high-level doses. In 2003, Yin et al. used doses of 0.1 Sv and 2.0 Sv applied to mouse brain. The 0.1 Sv dose induced expression of protective and repair genes, while the 2.0 Sv dose did not.

A similar study on human fibroblast cells was conducted in 2002 by Golder-Novoselsky et al. Using doses of 0.02 Sv and 0.5 Sv, they discovered that the 0.02 Sv dose induced stress response genes, while the 0.5 Sv dose did not. Several other microarray studies have demonstrated that high radiation doses, which serve as the “calibration” for LNT, are not equivalent to adding an accumulation of low radiation doses.

In fact, in 2001, Tanooka studied tumor induction by irradiating the skin of mice throughout their lifetimes. For irradiation rates of 1.5 Gy/week, 2.2 Gy/week, and 3 Gy/week, the percentage of mice that developed tumors was 0%, 35%, and 100%, respectively. This data demonstrated a clear threshold response directly in conflict with predictions of the LNT model.

E3. Effects of Low-Level Radiation on Biological Defense Mechanisms

In 1994, the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) report defined “adaptive response” as a type of biological defense mechanism that is characterized by sequent protection to stresses after an initial exposure of a stress (like radiation) to a cell. For radiation experiments, this is studied by exposing cells to low-doses to prime the adaptive response and then later exposing it to a high radiation “challenge dose” to see what happens. There have been several experiments in this topic, and we report on just a few of these.

In 1990, Cai and Liu exposed mouse cells in 2 different ways: (1) a high dose of 65 cGy (65 rad), and (2) a low-dose of 0.2 cGy before the high-dose of 65 cGy. The number of chromosome aberrations reduced in the second group compared to the first group was 38% bone marrow cell aberrations reduced to 19.5% and 12.6% spermatocyte aberrations reduced to 8.4 %.

In 1992, Shadley and Dai irradiated human lymphocyte cells, some with high doses and some with a low-dose a few hours before a high-dose. The number of chromosome aberrations caused by a high-dose was substantially reduced when a preliminary low-dose was given first.

In 2001, Ghiassi-nejad et al studied this effect in humans. In Iran, residents of a high background radiation area (1 cGy/year) were compared to residents in a normal background radiation area (0.1 cGy/yea). When lymphocytes, taken from these groups, were exposed to 1.5 Gy (150 rad), the percentages of aberrations were 0.098 for the high background area versus
0.176 (about double) for the low background area. The radiation in the high background area protected its residents from the 1.5 Gy dose.
E4. Stimulation of the Immune System

The effects of low-level radiation on the immune system are important since the immune system is responsible for destroying cells with DNA damage. Low doses of radiation exposure cause stimulation of the immune system while high doses reduce immune activity. \(^{71,72,78}\)

Contrary to expectations from the basic assumption of the LNT model (cancer risks depends only on total dose), effects on the immune system are quite different for the same total dose given at a low dose rate (summation of several small doses) versus one high dose rate, i.e., at low dose rates the immune system is stimulated, while at high doses, cancers are caused.\(^{49,55,56,79,106}\)

E5. Cancer Risks vs Dose (Animal Experiments)

To test the validity of the LNT model, there have been numerous direct experiments of cancer risk versus dose, with animals exposed to various radiation doses. In 1979, Ullrich and Storet\(^{116}\) reported that exposed animals lived up to 40% longer than controls. In a series of animal studies in the 1950s and 1960s, review articles by Finkel and Biskis\(^{40-42}\) reported, with high statistical significance, that the LNT model over-estimated the cancer risks from low-level radiation exposures; they reported a threshold not a linear response.

In a 2001 review of over 100 animal radiation experiments, Duport\(^{34}\) reported on studies involving over 85,000 exposed animals and 45,000 controls, with a total of 60,000 cancers in exposed animals and 12,000 cancers in control animals. In cases where cancers were observed in controls receiving low doses, either no effect or an apparent reduction in cancer risk was observed in 40% of the data sets for neutron exposure, 50% of the data sets for x-ray exposure, 53% of the data sets for gamma rays exposure, and 61% of the data sets for alpha particles exposure.

E6. Cancer Risks vs Dose (Human Experiments):

A. Critique of Data Frequently Cited in Support of LNT

The principle data, cited by those in influential positions, used to support the LNT model are those for solid tumors (all cancers except leukemia) in the survivors of the Japanese atomic bomb explosions. Pierce’s 1996 paper\(^{100}\) reported data from 1945-1990. By ignoring the error bars, supporters of the LNT model claim that the data suggests an approximate linear relationship with intercept near zero. But there is no data that gives statistical significant indication of excess cancers for radiation doses below 25 cSv.\(^{50}\) Leukemia data from Japanese A-bomb survivors strongly suggest a threshold above 20 cSv and the contradiction to the LNT model is recognized by the author.\(^{50}\) In 1998, Cohen\(^{27}\) used the three lowest dose points in the Japanese data (0-20 cSv) to show that the slope of the dose-response curve has a 20% probability of being negative (i.e., Hormesis = risk decreasing with increasing dose).

The next often cited evidence, by supporters of the LNT model, is the International Association for Research on Cancer (IARC) studies on monitored radiation workers. In 1995, Cardis et al\(^{13}\) reported on 95,673 monitored radiation workers in 3 countries and in a follow-up study by the same authors in 2005,\(^{14}\) they reported on 407,000 monitored workers in 154 facilities in 15 countries. In the first study, for all cancers except leukemia (there were 3,830 deaths, but no excess over the number expected from the general population), the risks were reported as -0.07/Sv with 90% confidence limits of (-0.4,+0.3), i.e., there is NO support for LNT from this data! However, for leukemia (146 deaths), they reported a positive correlation, but their data had no indication of any excess cancers (risks) below 40 cSv. Most importantly, these
authors manipulated their data by discarding 3/7 of their data points when observed/expected
was less than unity. It is suspected that this same “manipulation of data” was performed by the
same authors in the 2005 study. In fact, Cohen28 noted that (1) no information on such
confounding factors as smoking was given, (2) if data from just one of the 15 countries was
eliminated (Canada), the appearing excess is no longer statistically different from zero, (3) the
authors did not consider non-occupational exposure (natural background radiation) and if they
had, they would have noticed that their excess “signal” was much smaller than the “noise” from
background radiation.

Often critics of Radiation Hormesis use the “Healthy Worker effect” to discredit what is
found. When studying mortality rates for employed workers compared to the general population,
it is found that workers have lower mortality rates. In Sweden in 1999, Gridley48 compared
545,000 employed women to 1,600,000 unemployed women. He reported that the cancer
incidence rate was slightly higher for employed women (1.05 ± 0.01). This eliminated the claims
of the “Healthy Worker effect”. For an example of improper use of this effect, in 2005 Rogel105
studied 22,000 monitored workers in the French nuclear power industry. The cancer mortality
rate was only 58% of the general French population. Instead of concluding a Hormesis effect,
Rogel claimed that this large difference was due to the “healthy worker effect”.

Frequently, supporters of the LNT Model cite the recent BEIR Report30 as “proof” of the
LNT theory. However, this report has been rebutted.1 Aurengo reported on two French groups
who came to the opposite conclusions compared to the 2005 BEIR report.

Often in risk arguments, LNT supporters, eg Busseries et al.6 passionately present Tables
of the number of estimated cancer deaths per year as calculated from “known” x-ray usage in the
Berrington de Gonzalez study.3 The reader should note that such tables of deaths have been
ridiculed by Hiserodt,53 who asked “where are the bodies?” By this question, Hiserodt meant
that these deaths are estimates from the LNT theory without any deaths to support it.

Besides the rebuttal by Oakley et al93 to Busseries et al6, we note that this Berrington de
Gonzalez study3 relied solely on the LNT model and this study has been ridiculed by many for
several reasons. First, as several critics noted32,51,89,115 and for which the authors admitted in
their reply,4 they failed to weigh the benefits of diagnostic x-rays in their study, which only
guarantees an overestimate of death calculations. Another criticism was their assumption of the
LNT to make their cancer death estimations. Tubiana et al115 pointed out the “speculative
type” of the LNT hypothesis, and along with Simmons,110 noted that the LNT is only
compatible with exposures greater than 200mSv (drastically more radiation than any medical x-
rays).

Another criticism is that the Japanese survival data has significant limitations to
extrapolate its use for x-ray risk estimates from γ rays. The Japanese exposure was a one time
high dose, which is entirely different from accumulated small dose rates. Herzog and Rieger51
note that this data will overestimate cancer risk because the Japanese were exposed to γ rays
from bombs, a different energy spectrum than x-rays, but also the additional exposures of β
radiation, radionuclides emitting β and high-energy α radiation from contaminated water, food,
and dust.

Yet another criticism of the study was that there was no mention of the complexity and
effectiveness of the human cell’s defenses against ionizing radiation. Tubiana et al115 noted there
are hundreds of enzymes devoted to protect a cell from these effects and that “there is no single
defense mechanism but a variety,... an adaptive effect exists and a hormetic effect has even been
seen in more than half of experimental studies after low or moderate doses.\textsuperscript{10,35} “Extrapolation from high doses to low doses with LNT is unlikely to be able to assess the risks accurately.”\textsuperscript{115}

B. Data Contradictory to LNT

There is much data contradictory to the LNT model. There are multiple human studies which show a radiation Hormesis effect.

For breast cancer in Canadian women, Miller\textsuperscript{82} reported a decrease risk with increasing dose up to 25 cSv. Howe\textsuperscript{24} (for lung cancer in Canadian women) and Davis\textsuperscript{31} (for 10,000 people in Massachusetts) separately reported a decrease in cancers in the low-dose region up to 100 cSv. There is a difference between lung cancer rates in Japanese A-bomb survivors and the data from Howe and Davis: the Japanese survivors show a much higher risk at all doses. This indicates that one must not accept A-bomb survivor data (one large dose) to predict risks from low-dose rates where low-level doses are summed. It is known that risks from summing low doses (such as spinal radiography use in chiropractic) does not equal the risks from one large dose (Tubiana).\textsuperscript{114}

Kostyuchenko\textsuperscript{67} reported on a follow-up of 7,852 villagers exposed in the 1957 radioactive storage facility explosion in Russia. The cancer mortality rate was much lower in these villagers than in unexposed villagers in the same area supporting a hormetic effect. However, the exposure of the workers directly at the facility was quite high in one dose and these workers were found to have an increase in cancers indicating a dose threshold for increase cancers (Koshurnikova 2002).\textsuperscript{68}

In 1997, Sakamoto\textsuperscript{106} reported on radiation treatments in non-Hodgkin’s lymphoma. Patient groups were randomly separated into radiation treatment and non-radiation treatment. After 9 years, 50\% of the control group died but only 16\% of the irradiated group died.

The conclusion from Cohen’s outline\textsuperscript{28} is that the LNT theory fails badly in the low dose region. It grossly over-estimates the cancer risks from low-level radiation. The cancer risk from the vast majority of normally encountered radiation exposures (background radiation, medical x-rays, etc...) is much lower than estimates given by supporters of the LNT model, and it may well be zero or even negative.

F. Implications for X-ray Guidelines

In summary, it is noted that over the last 100 years, the public’s impression of the risks of medical x-rays has gone from “health benefits with insignificant risk”, to “benefits must be weighed against risks”. In the case of the Chiropractic profession, the situation is even worse; recently a subgroup of DACBRs have campaigned to attempt to force the profession to the position of only using x-rays when "Red Flags" are apparent in order to justify "benefits" over "potential" risk.

It is the conclusion of this section of this document that after reviewing the LNT Model and the Hormesis Model, it is the opinion of the PCCRP expert panel that a return to, “Benefits versus Risks”, for chiropractic x-rays is needed at present and that evidence has shown that the risks from x-rays are much less than the perception currently held by the general public.

We end this section on Radiation Exposure with a 2005 quote from Hiserodt,\textsuperscript{53} “The LNT theory has created irrational and unwarranted fears in citizens, causing them needless worry over their essential medical X-rays”.\textsuperscript{53} “Sadly, an unwarranted fear of radiation causes many people who could be benefited by the use of X-ray diagnosis and therapy to shun such treatments-and thereby become subjected to unnecessary real dangers.”\textsuperscript{53}
References


2. Azzam EI, de Toledo SM, Raaphorst GP, Mitchel REJ. Low dose ionizing radiation decreases the frequency of neoplastic transformation to a level below spontaneous rate in C3H 10T1/2 cells. Radiat Res 1996;146:369-373.


123. [http://www.epa.gov/radiation/students/calculate.html]: Student’s and Teacher’s Resource of the US Environmental Protection Agency; “Calculate Your Radiation Dose”. Average Annual Radiation Dose Calculator in mrem.

124. [http://www.physics.isu.edu/radinf/popdose.htm]: Idaho State University Department of Physics; Sources of Radiation Exposure to US Population. Adapted from NCRP Report 93.


VIII. Reliability of Geometric Line Drawing Radiographic Analysis

RECOMMENDATION

Radiographic line drawing procedures for spinal and lower extremity positions have been subjected to a large volume of inter and intra examiner reliability studies. The overwhelming majority of these studies have found that examiner reliability is in the excellent range and thus can be used for the clinical evaluation of spinal subluxation by chiropractic clinicians.

Supporting Evidence: Reliability Studies Class 1 and 2.

PCCRP Evidence Grade: Reliability Studies = a and b.

Introduction

Even though there has been a plethora of inter and intra-examiner reliability studies performed on geometric line drawing analysis on radiographs of all regions of the spine and extremities,1-148 some Chiropractic radiologists and academics still continue to claim that “there is little or no evidence to support reliability of x-ray line drawing analysis”.149 With nearly 150 published papers on this topic, geometric x-ray line drawing of spinal displacements is one of the most studied topics in the indexed literature.

In a recent Chiropractic text, regarding x-ray line drawing, Peterson and Hsu150 stated, “...attempts to evaluate the reliability (ability to obtain the same measurements on more than one occasion or between different examiners) have given conflicting results.” In support of this statement, Peterson and Hsu150 provide 3 references. The first of these references is from Haas et al149; this was not a review of the relevant reliability studies but a dissent largely based on Class V evidence. Importantly, this opinion article149 was subsequently thoroughly critiqued.151 The second reference provided by Peterson and Hsu150 appears to be a student paper written for a non-post graduate degree and is rather odd to be used as a scientific source for such a statement. The third study cited by Peterson and Hsu150 in their attempt to curtail the reliability of x-ray line drawing procedures is a study on ‘visual’ estimation of lumbar lordosis and did not utilize line drawing methods whatsoever.152 Interestingly, this article152 was subsequently thoroughly critiqued.153

The above scientific facade of references to support the agenda that x-ray line drawing in chiropractic is not reliable or at best has questionable reliability is not an isolated event in chiropractic literature. For example, in a literature review of subluxation assessment methods, Owens154 stated that the reliability of lumbar x-ray line drawing methods is ‘poor to nonexistent’. In support Owens154 (like Peterson and Hsu150) used the Haas et al149 study and also a study by French et al.155 Of interest, the study by French et al155 did not assess lumbar line drawing methods and, in fact, no measurements were made on x-rays what so ever.

As mentioned in an earlier section, these ‘pseudo-scientific’ radiography articles and chapters, written by a minority group of publishing DACBRs and academics, are used by Managed Care Organizations (MCO’s) (such a ACN and ASHN)156 to deny coverage for radiology services for patients seeking chiropractic care. Thus, it may be that these radiology articles and texts are aiding a situation where the chiropractic clinician is removed from the patient treatment decision making process such that costs can be ‘controlled’ and profits can be ‘maximized’.157
The shear number and quality of studies demonstrating sufficient reliability of geometric line drawing analysis on radiographs of all regions by Chiropractors, Medical Doctors, and Orthodontists will hopefully allow this information to gain acceptance and aid in proper dissemination of the evidence.

In an effort to dispel the generalized Class V (expert opinion) evidence that radiographic line drawing procedures are unreliable, the current PCCRP Guideline panel decided to provide tables of reliability studies in each region of the spine and pelvic area in this section. Another reason for our separate tables of each region and each type of study (AP, lateral, flexion/extension) is to benefit the reader’s future ease of finding the appropriate study for any area of radiographic investigation from the approximately 148 published studies on this topic.

The arrangement of the following Tables (1-12) is by region and by view: Head, AP Cervical and nasium, lateral cervical, cervical flexion/extension, AP thoracic and AP full spine, lateral thoracic, AP lumbar and Ferguson, lateral lumbar, lumbar flexion/extension, lateral full spine, AP and lateral pelvis, and lower extremity.

Summary

This volume of literature determining the reliability of x-ray line drawing procedures for spinal, pelvic, and extremity alignment, is contradictory to the Class V evidence but forth by a subgroup of chiropractic Radiologists and some chiropractic academics. The radiographic assessment using geometric line drawing methods to determine the displacement component of Chiropractic spinal subluxation is reliable and has small errors.

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al, 2000</td>
<td>Lateral head &amp; Neck 10 films, 7 residents</td>
<td>Inter-observer error on digital images was &gt; than on radiographs; significant differences only in 4/19 landmarks</td>
</tr>
<tr>
<td>Chen YJ et al, 2004</td>
<td>Lateral head &amp; Neck 10 films, 7 examiners</td>
<td>Radiographs &amp; digitized images: Differences in 21 of the 27 cephalometric items were less than two units of measurement (mm or degree). Inter-observer errors on digitized images are comparable to radiographs and are clinically acceptable</td>
</tr>
<tr>
<td>Gliddon MJ et al, 2006</td>
<td>8 films, 2 examiners</td>
<td>Error of both manual &amp; LS-5 methods was 0.5 mm. The LS-5 method had its advantage because it could be automated by computer</td>
</tr>
<tr>
<td>Hermann NV et al, 2001</td>
<td>40 films, 1 examiner</td>
<td>Error due to landmark digitization determined by Dahlberg's formula was 0.8 mm for linear variables &amp; 1.6 degrees for angular variables</td>
</tr>
<tr>
<td>Wah PL et al, 1995</td>
<td>60 films, 1 examiner</td>
<td>No significant differences in landmark location &amp; measurement between the orthodontic &amp; surgical patient groups. Extreme variations in skeletal morphology do not affect accuracy of cephalometric evaluation</td>
</tr>
</tbody>
</table>
## Table 2. AP Cervical (& Nasium) Reliability Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addington EA, 1986 and 1987</td>
<td>Blair technique nasium, condyle</td>
<td>80-90% agreement between examiners measurement of upper cervical subluxation on the Blair technique views.</td>
</tr>
<tr>
<td>Eriksen K.</td>
<td>Review of Literature</td>
<td>Reported on the studies demonstrating inter and intra examiner reliability for upper cervical measures of atlas laterality. Reliability in the good to excellent range for all measures.</td>
</tr>
<tr>
<td>Harrison DE et al, 2002</td>
<td>30 films, 3 examiners.</td>
<td>8 Intra- &amp; Inter- examiner ICCs &gt; 0.88. Observer error was in the interval (0.8°- 3.2°) for angles and &lt;1 mm for distances.</td>
</tr>
<tr>
<td>Jackson BL et al, 1987</td>
<td>30 films, 6 examiners.</td>
<td>Reliability (stability over time) for the practitioners is very good. Reliability (equivalence over experts) across the practitioners is very good. The standard error of measurement for 6 examiners was 0.41° for the upper angle and .61° for the lower angle.</td>
</tr>
<tr>
<td>Jackson et al, 1988</td>
<td>38 nasiums, 3 examiners, 2 occasions.</td>
<td>Inter- &amp; Intra-examiner Pearson’s r &gt; 0.92. Standard error of measurement for Upper angles (UA) &lt; 0.5° and SEM for lower angles (LA) &lt; 0.8°.</td>
</tr>
<tr>
<td>Jackson et al., 2000</td>
<td>2x38 nasium.</td>
<td>After sham adjustment: All measures ≤ 1.0° between 38 sets of pre-post nasiums.</td>
</tr>
<tr>
<td>Janik TJ et al, 2001</td>
<td>30 films, 3 examiners.</td>
<td>For axial rotation, the intra-class ICCs ≥ 0.78, and the inter-class ICCs ≥ 0.67. For lateral flexions (Rz) of C3-T3, all intra-class and inter-class ICCs &gt; 0.87.</td>
</tr>
<tr>
<td>Owens EF Jr, 1992</td>
<td>AP Nasium &amp; Vertex Review</td>
<td>Reliability studies report inter- and intra-examiner reliability are sufficient to measure lateral and rotational displacements of C1 to within ± 1° on the Nasium x-ray.</td>
</tr>
<tr>
<td>Rochester RP, 1994</td>
<td>4 blind examiners, 2 occasions, 10 sets (30 film),</td>
<td>Manual and CAD X-ray analysis reliabilities of the UA, LA, C1 and C2 rotation relative to the skull, geometry of the condylar and axial surfaces and Height Factor or vector angle for the adjustment. It reported good to excellent reliabilities. The side of the UA was in 100% agreement 120/120 measurements. It also confirmed the findings of the Jackson study with an intra-examiner standard error of the UA measurement of 0.45 vs. 0.41 degrees for Jackson, et. al.</td>
</tr>
<tr>
<td>Seeman et al, 1994</td>
<td>1 film, 43 examiners</td>
<td>Atlas laterality was determined by angular measurement on the nasium film. The mean difference was 0.55°. 40% of the group was within 0.25° and almost 75% were within 1°. Only 1/43 doctors found found laterality on the opposite side.</td>
</tr>
<tr>
<td>Sigler, Howe, 1985</td>
<td>20 nasium films, 2 examiners, Atlas laterality</td>
<td>The absolute average of 20 measures was 1.55° for one examiner, with an average absolute difference between each pair of measures of 1.10°. For the intrarater assessment of examiner 2 the corresponding numbers were 2.01° and 0.82°. Intraclass correlation coefficients ranged from 0.70 to 0.86. Note: This study has been critically reviewed.</td>
</tr>
<tr>
<td>Spencer 1989</td>
<td>Experienced examiners vs. students, nasium</td>
<td>Atlas laterality (UA) on the nasium was found to have an inter-examiner error of 0.33°. Experienced doctors versus students did not affect the error margin.</td>
</tr>
<tr>
<td>Troyanovich et al, 2000</td>
<td>30 films, 3 examiners</td>
<td>Intra-examiner ICC’s were : 1) T(x) distance 0.99 -1.00, 2) vertebral apex ICC’s 0.96-0.97; 3) Rz: 0.94-0.98; 4) CDA: 0.92- 0.95. Inter-examiner for 3 examiners ranged (0.97-0.99).</td>
</tr>
</tbody>
</table>
Table 3. Lateral Cervical Reliability Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cote P et al, 1997</td>
<td>30 films, 3 examiners</td>
<td>Apophysial joint degen: Intra-CC = 0.45 degen disc disease: Intra-CC = 0.71; Cobb C2-C7 Intra-CC = 0.96, error =8.3°.</td>
</tr>
<tr>
<td>Frobin W et al, 2002</td>
<td>135 films</td>
<td>Height C3-C7 &amp; disc height C2/C3-C6/C7 small errors of 3.9% and 5.7%. PA displacement C1/C2 to C6/C7 small error of 2.8% of mean vertebral depth &amp; dens-atlas gap small error of &lt;1.8% of the depth of C2.</td>
</tr>
<tr>
<td>Harrison DE et al 2000</td>
<td>30 films, 3 examiners</td>
<td>Posterior tangents are more reliable than Cobb angles, SEM ≤ 3°, 28out of 34 Intra- &amp; Inter- ICCs were &gt; 0.7; the other 6 were 0.6 &lt; ICC &lt; 0.7.</td>
</tr>
<tr>
<td>Hardacker JW et al, 1997</td>
<td>30 films, 2 examiner</td>
<td>Intra- &amp; inter-observer ICCs for sagittal alignment measures had strong correlation.</td>
</tr>
<tr>
<td>Herrmann AM, Geisler FH, 2004</td>
<td>27 films, 4 examiners</td>
<td>High intra- &amp; inter-class correlations &amp; low measurement errors (1.8° &amp; 0.7mm).</td>
</tr>
<tr>
<td>Jackson BL et al, 1993</td>
<td>65 films, 3 examiners</td>
<td>For all segmental &amp; global angles intra- &amp; inter-examiner ICCs &gt; 0.70.</td>
</tr>
<tr>
<td>Marshall and Tuchin, 1996</td>
<td>500 films, 2 observers,</td>
<td>Lordosis C1-C7 was evaluated. The mean absolute differences in rating between examiner one and two was 0.9 degrees. Mean signed difference = 0.04 with a 95% CI (-0.07, 0.14). The SD of differences is 1.17 so that 95% of differences in ratings between individual patients in the population from which this sample is drawn are predicted to lie in the range -2.31 to 2.38.</td>
</tr>
<tr>
<td>Peterson et al, 1999</td>
<td>48 films</td>
<td>Interexaminer and intraexaminer reliability of determining pillar hyperplasia was fair to substantial (kappa = 0.4 to 0.61; 75% to 92%).</td>
</tr>
<tr>
<td>Rochester, RP 1994</td>
<td>4 examiners, 2 occasions, 10 sets (30 film),</td>
<td>Four blinded examiners measured and re-measured 10 lateral films for the atlast plane line-“S-Line”. Two examiners used manual marking methods and two examiners used CAD. Reliability for the S-Line measurement was 0.70 – 0.95, good to excellent with small measurement errors.</td>
</tr>
<tr>
<td>Shoda N et al, 2005</td>
<td>30 films, 5 examiners</td>
<td>Intra-observer mean errors: Chamberlain line, McRae line, &amp; McGregor line were 2.0°, 4.7°, &amp; 1.5° respectively; intra-observer ICCs: 0.956, 0.835, and 0.975. Inter-observer mean errors: Chamberlain line, McRae line, &amp; McGregor line were 2.3°, 5.0°, &amp; 1.4° respectively; inter-observer ICC were: 0.939, 0.802, &amp; 0.972.</td>
</tr>
<tr>
<td>Siersbaek-Nielsen &amp; Solow, 1982</td>
<td>30 patients, 2 occasions 1-35 days, 3 examiners</td>
<td>Error: whole group was 2.3° for head position in relation to true vertical (NSL/VER), 3.1° for cervical inclination (OPT/HOR), and 3.4° for craniocervical angulation (NSL/OPT).</td>
</tr>
<tr>
<td>Silber JS et al, 2005</td>
<td>40 films, 3 examiners</td>
<td>Less intra- &amp; interobserver variability for Gore method than for Cobb method (P &lt; 0.05). 95% confidence limits for intra- &amp; interobserver variability for Gore method were 3°- 6° for group 1 &amp; 4°- 7° for group 2. Cobb method, values were 4°- 9° for group 1 &amp; 5°- 9° for group 2.</td>
</tr>
<tr>
<td>Stupor et al, 2003</td>
<td>50 radiographs, 2 examiners</td>
<td>Inter-examiner reliability of detecting cervical pillar hyperplasia was moderate with a kappa coefficient of 0.51.</td>
</tr>
<tr>
<td>Weigand et al, 2003</td>
<td>1 film digitized 10 times, 2 examiners</td>
<td>Of the 22 measurements obtained, 20 measurements demonstrated a SD of less than 20% of the average measured value. The inter-examiner SD’s were within 1 degree and 1 mm for 20/22 measurements.</td>
</tr>
<tr>
<td>Takeshita K et al, 2001</td>
<td>295 films, 1 examiner</td>
<td>Mean cervical curvature index (Ishihara) = 10.9 ± 15.3 &amp; mean C2-7 angle = 20.3° ± 14.3°. A highly significant correlation (0.95) was found between cervical curvature index (Ishihara) &amp; C2-7 angle. Correlation diminished with S-shape.</td>
</tr>
</tbody>
</table>
### Table 4. Flexion/Extension Cervical Reliability/Validity Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannada LK, 2003</td>
<td>27 films, 3 examiners</td>
<td>Cronbach's alpha: 0.95 for spinous process method &amp; 0.74 for Cobb angle.</td>
</tr>
<tr>
<td>Capaccioli L et al, 1998</td>
<td>31 films, 4 examiners</td>
<td>Results show a high level of agreement of absolute measurement error between examiners.</td>
</tr>
<tr>
<td>Dvorak et al, 1988</td>
<td>28 healthy adult, 31 patients, 2 examiners</td>
<td>Penning’s method: No statistically significant difference at any level was found when comparing the results of Examiner 1 with Examiner 2. Buetti-Bauml method: Produced significant interobserver difference in some of the measured values.</td>
</tr>
<tr>
<td>Frobin W et al, 2002</td>
<td>137 films</td>
<td>Segmental motions: Small errors (2° &amp; 0.7mm), Quantifies segmental motions: Hyper, hypo, normal.</td>
</tr>
<tr>
<td>Harrison DE et al, 2000</td>
<td>30 films, 3 examiners</td>
<td>34 intra- &amp; inter-class ICC, 28 were in the high range (&gt;0.7), and 6 were in the good range (0.6-0.7). Cobb C1-C7 overestimated the cervical curvature (-54 degrees); at C2-C7 it underestimated cervical curve (-17 degrees ), from posterior tangents (-26 degrees from C2 to C7). Inferior vertebral endplates and posterior body margins did not meet at 90 degrees: C2: 105°, C3: 99.7°, C4: 99.9°, C5: 96.1°, C6: 97.0°, C7: 95.4°, so segmental Cobb angles to underestimate lordosis at C2-C3, C4-C5, C6-C7.</td>
</tr>
<tr>
<td>Lind B et al, 1989</td>
<td>70 films, 1 examiner</td>
<td>Intra-observer error = ±1.8°. Range of axial rotation was measured (compass) on the subject's head. Intra-observer error with this technique was ±6 °. Largest flexion-extension motion occurred at C4/C5 and C5/C6. A linear decrease of motion in all directions, except flexion, was found with age.</td>
</tr>
<tr>
<td>Phillips FM et al, 1999</td>
<td>30 sets, 1 examiner</td>
<td>Radiographic measures of occipitocervical neutral position are reliable, repeatable, and simple to determine on routine lateral radiographs.</td>
</tr>
<tr>
<td>Schops P et al, 1999</td>
<td>40 films, 5 examiners</td>
<td>Selectivity of p &lt; or = 0.05 and p &lt; or = 0.01 is sufficient to distinguish patients from healthy subjects. The correlation between reviewers showed good to very good results (0.6 &lt; r &lt; or = 0.8; r &gt; 0.8).</td>
</tr>
<tr>
<td>Wellborn CC et al, 2000</td>
<td>144 films, 3 examiners</td>
<td>ADI has greatest intraobserver agreement compared to Wiesel-Rothman measurement, occiput atlas angle, and Power’s ratio. Fair interobserver agreement for ADI and Wiesel-Rothman, &amp; better than Power’s ratio.</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Films, Examiners</td>
<td>Findings</td>
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<td>----------------------</td>
<td>-------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Adam CJ et al, 2005</td>
<td>12 CT scans, 5 examiners, 3 occasions</td>
<td>For major curves, 95% confidence intervals for intra- &amp; inter-observer ±6.6° &amp; ±7.7°, respectively. For minor curves, the intervals ±7.5° &amp; ±8.2°, respectively. Intra- &amp; inter-observer error of measurement 2.4° &amp; 2.7°, with reliability coefficients of 88% &amp; 84%, respectively.</td>
</tr>
<tr>
<td>Adam CJ, Askin GN, 2006</td>
<td>19 CTs, 3 examiners, marked 3 times</td>
<td>Confidence intervals (95%) for intraobserver &amp; interobserver variability using manual methods were 5.5°-7.2°. Mean difference between automatic and manual rotation measurements was -0.5° ± 3.3° for Aaro's method &amp; 0.7° ± 3.4° for Ho's method. Mean difference between automatic &amp; manual rotation measurements for the 204 endplate images was 0.25 ±3.8°.</td>
</tr>
<tr>
<td>Beekman, Hall, 1979</td>
<td>2 examiners, 10 films Full spine films, measured one time, Cobb method where examiners choose curve levels each time</td>
<td>Mean absolute values of observer differences: 4.2° ± 95°. 95% confidence interval was calculated as: 2.1°-6.3°. Pearson r = .66, p &lt; 0.025. Note: that this study allowed examiners to choose the curve end points. With defined endpoints, errors are much smaller.</td>
</tr>
<tr>
<td>Berliner Let al, 2002</td>
<td>5 films, 1 examiner</td>
<td>Cobb data indicates an accuracy within 1 to 2 degrees for two computer methods: AccurView &amp; Osiris</td>
</tr>
<tr>
<td>Burk et al, 1990</td>
<td>20 films, 2 examiners</td>
<td>Cohen’s kappa was used for assessing inter-rater agreement. Intra-rater reliability of examiner 1 was “fair” at each of the 6 pre-selected spinal levels. Examiner 2 obtained reliability of “moderate” at 4/6 of the preselected levels and “fair” for the other 2/4. Inter-rater reliability at 4/6 of the sites was “slight” and “fair” at the remaining 2/6.</td>
</tr>
<tr>
<td>Carmen et al, 1990</td>
<td>8 scoliosis, 20 kyphosis, 5 observers, 2 occasions</td>
<td>Overall standard deviation (the square root of the variance-component total) was 2.97 degrees. The square root of the intraobserver variance component is 2.78 degrees. The value of K for the sample of eight is 2.43813. Ion absence of any true change one can be 95% confident that 95% of the time the second value for the Cobb angle will be no more than 9.6 degrees more or less than the first due to observer error alone.</td>
</tr>
<tr>
<td>Cheung J et al, 2002</td>
<td>AP &amp; lateral: 30 AP, 10 lateral, 5 observers</td>
<td>Mean intraobserver CR = 3.1 ° for AP Cobb angle &amp; 3.3° for kyphosis Cobb angle. mean difference in the intraobserver CR of the Cobb angle between measurements made by placing landmarks and those made by drawing lines was not statistically significant (P&gt;0.05). The mean intraobserver CR for the other parameters: for lateral deviation it was 0.8 mm, for axial rotation 4.0 ° and for length of the spine 3.3 mm.</td>
</tr>
<tr>
<td>Chockalingam N et al, 2002</td>
<td>9 films, 10 observers, 3 occasions</td>
<td>Computerized method: Intra-observer technical error of measurement (TEM) = 0.739° (98% error free), inter-observer TEM = 1.22°, mean coefficient of reliability = 0.988 Manual method: inter-observer TEM = 1.858°, coefficient of reliance = 0.781.</td>
</tr>
<tr>
<td>Dang NR et al, 2005</td>
<td>10 films, 2 examiners, 5 times</td>
<td>PA &amp; lateral: Intra-examiner reproducibility was generally excellent for parameters measured from PA radiographs but only fair to good for parameters from the lateral radiographs, in which some landmarks were not clearly visible. 7/13 parameters had excellent inter-observer reliability.</td>
</tr>
<tr>
<td>Desmet et al, 1982</td>
<td>78 patients (128 curves), 2 films taken same day-AP vs. PA, 2 observers</td>
<td>Angles were highly correlated (r=0.96). The PA radiographs revealed a larger curve for the thoracic curves (2.4 degrees, P&lt;0.0001) and lumbar curves (1.7 degrees, P&lt;0.031) nd the same for thoracolumbar curves.</td>
</tr>
<tr>
<td>Goldberg et al, 1988</td>
<td>30 films, 4 observers</td>
<td>Excellent intracllass correlation coefficients (Rho= 0.98). The standard deviation of intraobserver variation for the measured “primary” Cobb angle was 2.5 degrees and the intra-reader error, based upon the re-assessment of 15 films was 1.9 degrees. The “secondary” Cobb angle had an interrater agreement lower (Rho= 0.52), because smaller curves were less often noticed.</td>
</tr>
<tr>
<td>Gross et al, 1983</td>
<td>20 films, 28 scoliotic curves, 3 observers, 10 times each (5 manual+5 digitized)</td>
<td>2 way ANOVA showed no significant differences among the 3 observers or between the 2 methods. The correlations for the three observers were 0.94, 0.93 and 0.87. All these correlations were significant at p&lt;0.01.</td>
</tr>
<tr>
<td>Jeffries et al, 1980</td>
<td>157 films, 5 examiners</td>
<td>Cobb method was compard with a computerized method. There was a 0.968 positive correlation between methods. Standard deviations for the manual Cobb method were between 2.1 and 3.6 degrees.</td>
</tr>
<tr>
<td>Kittleson and Lim, 1970</td>
<td>Opinion paper/review</td>
<td>Ferguson method should be used for curves under 50 degrees and the Cobb method for those curves over 50 degrees.</td>
</tr>
</tbody>
</table>
Table 5B. AP/PA Thoracic and AP Full Spine Reliability Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuklo TR et al, 2005</td>
<td>30 sets of pre-post, PA, lateral &amp; side bending: common radiographic parameters for AIS assessment demonstrated good or excellent reliability for digital measurement and can be recommended for routine clinical &amp; academic use.</td>
<td></td>
</tr>
<tr>
<td>Kuklo TR et al, 2005</td>
<td>30 sets, 3 examiners PA &amp; lateral &amp; side bending: majority of the radiographic parameters assessed demonstrated good or excellent intra- and inter-examiner reliability.</td>
<td></td>
</tr>
<tr>
<td>Kuklo et al, 2006</td>
<td>30 AP full spine and bending films, 2 examiners, 9 variables, 2 times by hand, 2 times digitally. Digital measurements showed decreased variability for 6/9 variables, however magnitudes were small. Combined intraobserver error for both methods: Cobb angle = 2°-3°, Side bending Cobb = 3°-4.3°, Plumbline to apex = 3.4mm-4.4mm, Coronal balance = 2.8mm-3.8mm, T1 Tilt = 2.3°-3.13°, LV Tilt = 2.6°-3.0°, L1 inferior disc angle = 2.15°-2.8°, Apical rotation = 0.23°-0.43°, Riser grade = 0.31°-0.79°.</td>
<td></td>
</tr>
<tr>
<td>Lantz et al, 2001</td>
<td>40 curves, 1 examiner, 2 times Demonstrated a minimal 0.6° margin of error for intra-examiner test-retest reliability.</td>
<td></td>
</tr>
<tr>
<td>Morrissy et al, 1990</td>
<td>50 films, 4 observers The pooled results of all four observers suggested that the 95 per cent confidence limit for intraobserver variability was 4.9 degrees for Set I, 3.8 degrees for Set II, and 2.8 degrees for Set III. The interobserver variability was 7.2 degrees for Set I and 6.3 degrees for Sets II and III.</td>
<td></td>
</tr>
<tr>
<td>Neugebauer et al, 1972</td>
<td>2 spines, several exposures with axial rotation of specimen and tube tilt Absolute differences between the control and the examined exposures had a mean value of 1.15 +/- 0.98 for the Ferguson method and 2.06 +/- 1.09 for the Cobb angle in the first specimen and 0.60 +/- 0.21 and 0.98 +/- 0.31 degrees, respectively for the second. Axial rotation of the spine or elevation of the tube alone or in combination produced “differences in the measurements of the spinal deformity, which, however, hardly surpass the margins of error of the measurements.”</td>
<td></td>
</tr>
<tr>
<td>Oda et al, 1982</td>
<td>50 AP full spine films, 5 observers, 2 occasions. Average error was +/- 9 degrees (Cobb angle). The design of the study forced examiners to choose the end vertebrae blindly from test to re-test. This is where most error occurs. This would not be the case when a doctor is marking pre and post films in a clinical setting.</td>
<td></td>
</tr>
<tr>
<td>Omeroglu et al, 1996</td>
<td>3 patients, 54 observers (grouped according to experience) No statistically significant difference (P &gt; 0.05) between the averages of the final measurements of the three groups of examiners. The one film with the largest Cobb angle and largest apical rotation, significant difference (P = 0.03) between groups. Intra-observer variation, no statistically significant differences for apical rotation (P &gt; 0.05).</td>
<td></td>
</tr>
<tr>
<td>Prujs et al, 1994</td>
<td>Phase 1: 10 fusion scoliosis patients, 3 serial radiographs Phase 2: 46 x-rays, 3 observers Phase 1: The standard error in the production of the radiograph on the same patient with a series of 3 films (the second and third films being taken at least one year following the first) was 2.2 degrees. The standard error of interobserver measurement variation was 1.4 degrees. Extent of error was not associated with magnitude of Cobb angle.</td>
<td></td>
</tr>
<tr>
<td>Russell GG et al, 1990</td>
<td>8 vertebral positions, 3 examiners No significant difference in calculated rotation of two vertebrae, or between three markers. Stokes's method was significantly the least accurate. The other three methods were not significantly different but Bunnell's method appeared to give more consistent results.</td>
<td></td>
</tr>
<tr>
<td>Sevastikoglou et al, 1969</td>
<td>1 scoliotic skeleton, then taken apart and reassembled The absolute differences in measurements between the control and the examined exposures had a mean value of 1.15 +/- 0.98 degrees for the Ferguson measurement and 2.06 +/- 1.09 for the Cobb method in the first specimen and 0.66 +/- 0.21 and 0.98 +/- 0.31 for the second.</td>
<td></td>
</tr>
<tr>
<td>Shea KG et al, 1998</td>
<td>AP scoliosis 24 films, 6 examiners Manual measurements: intraobserver variability was 3.3 degrees. For the computer set, the value was 2.6 degrees.</td>
<td></td>
</tr>
<tr>
<td>Taylor JA, 1993</td>
<td>Review, reliability &amp; clinical relevance AP full-spine radiography is an effective diagnostic and analytic procedure with an acceptable risk/benefit ratio. “Promising to excellent inter- and intraobserver reliability for some parameters.”</td>
<td></td>
</tr>
<tr>
<td>Wilson et al, 1983</td>
<td>1 x-ray, 38 examiners The average curve measured was 22.2 degrees (SEM=+/-.084 degrees).</td>
<td></td>
</tr>
<tr>
<td>Ylikoski et al, 1990</td>
<td>30 scoliosis films The 95% confidence interval for the interobserver error when measuring the scoliotic angle and % vertebral rotation was 5.7° and 6.9%. The intraobserver error was reported at a 95% CI = 3.7 deg and 3.7% for scoliosis angle and axial rotation, respectively. The interobserver measurement error (SD) was 2.8° for the Cobb angle and 1.8% for the vertebral rotation.</td>
<td></td>
</tr>
<tr>
<td>Zmurko MG et al, 2003</td>
<td>50 films, 4 examiners No significant difference in the intra-observer or inter-observer variance between the digital and traditional groups. Digital radiographs are comparable to traditional radiographs.</td>
<td></td>
</tr>
</tbody>
</table>
## Table 6. Lateral Thoracic Reliability Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goh S et al, 2000</td>
<td>95 films, 3 methods</td>
<td>Strong correlations between angle and curvature for all 3 methods.</td>
</tr>
<tr>
<td>Harrison DE et al, 2001</td>
<td>30 films, 3 examiners</td>
<td>All three methods: global angle inter- &amp; intra-examiner ICC &gt; 0.94. Segmental angles, inter-observer and intra-observer ICCs in ranges (0.59-0.75 and 0.75-1.0). Mean absolute differences of observers' measurements are small (0.9°-2.5°).</td>
</tr>
<tr>
<td>Kado DM et al, 2006</td>
<td>120, 1 examiner</td>
<td>Mean of both the manual and digitized Cobb angle was 45 degrees (range 18°-83°), mean Debrunner kyphometer reading was 48°(range 17°-83°). ICC between either of the 2 measures of the Cobb angle and Debrunner measurement was 0.68. ICC between the manual and digitized Cobb angle was 0.9.</td>
</tr>
<tr>
<td>Keynan O et al, 2006</td>
<td>Systematic review</td>
<td>Recommend radiographic parameters routinely for thoraco-lumbar fractures: Cobb angle, for sagittal alignment; vertebral body translation %, for traumatic anterolisthesis; anterior vertebral body compression %, for vertebral body compression, the sagittal-to-transverse canal diameter ratio, &amp; canal total cross-sectional area; % canal occlusion, for canal dimensions.</td>
</tr>
<tr>
<td>Kuklo TR et al, 2001</td>
<td>50 films, 3 examiners</td>
<td>Intraclass correlation coefficients best method 1 (rho = 0.83-0.94); Method 4 (rho = 0.65-0.89); Method 5 (rho = 0.73-0.85). Intra-observer agreement (% of repeated measures within 5 degrees of the original measurement) ranged between 72% and 98% for all techniques for all three observers; inter-observer reliability correlation coefficients ranging from 0.52 - 0.93. Method 1 highest inter-observer reliability coefficient (0.81, range 0.71-0.93) followed by Method 5 (0.71, range 0.68-0.75).</td>
</tr>
<tr>
<td>Rosol et al, 1996</td>
<td>23 films, 5 examiners—digitized films—morphometry</td>
<td>The coefficient of variation for interobserver variation was 2%. The mean deviation of an individual examiner from the group average was 0.63+/-.62 mm. Interobserver variability was also minimal, with differences in measured values falling between 3 to 5% and randomly distributing around zero. Regarding validity, a phantom was used with known dimensions. Measurements were distributed around the National Institute of Standards and Technology standards, indicating no systematic error. Longitudinal reproducibility was studied using 20 cases of 3 serial thoracic and radiographic studies, each one year apart. Coefficient of variability for the three aspects on the vertebral body height (anterior, middle and posterior) were low (4-6%).</td>
</tr>
<tr>
<td>Singer KP et al, 1990</td>
<td>286 films, 1 examiner</td>
<td>Computer method was more reliable, producing a coefficient of variation of 1.4% on repeated measurement.</td>
</tr>
<tr>
<td>Singer KP et al, 1994</td>
<td>22 films, 1 examiner</td>
<td>In vivo and in vitro measurements strongly correlated (Cobb angle r = 0.95, curvature r = 0.78). Trends decreased slightly in Cobb angle (1.3%, -2.6%) and increased slightly in curvature (10.7 mm, 4.1%).</td>
</tr>
<tr>
<td>Stotts AK et al, 2002</td>
<td>30 films, 4 examiners</td>
<td>Intraobserver variance = 4.3°. One examiner had significantly better precision (P= 0.02). This examiner's mean intra-observer difference= 2.3°.</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Films, Examiners</td>
<td>Findings</td>
</tr>
<tr>
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</tr>
<tr>
<td>Haas et al, 1990</td>
<td>43-58 AP lumbar and bending films, 3 examiners, 1 time</td>
<td>Inter-segmental lateral bending and rotation angles. Majority of mean absolute differences between observers was 2° or less. Level of agreement for rotation around gravity was greater. L1-L4 reliability was determined to be good while L5 was poor. However, the 3rd examiner received copies instead of actual radiographs.</td>
</tr>
<tr>
<td>Harrison DE et al, 2002</td>
<td>30 films, 3 examiners</td>
<td>5 Intra- &amp; Inter-examiner ICCs &gt; 0.88. 3 ICC values (0.61, 0.76, 0.78) concerned determining the sacral base. Mean absolute differences of observers' measurements were 1.1 degrees to 1.8 degrees for angles and 1.2 mm to 2.3 mm for distances.</td>
</tr>
<tr>
<td>Quint DJ et al, 1997</td>
<td>AP &amp; lateral lumbo-sacral: films, examiners??</td>
<td>Intra- and inter-observer measurement of spondylo-listhesis, disk space height, disk space angle, and vertebral body height are extremely reproducible.</td>
</tr>
<tr>
<td>Thorkeldsen A, Breen AC, 1994</td>
<td>8 films, 10 measurements, 1 examiner</td>
<td>For radiographs of diagnostic quality the gray scale range and midpoint level over the area of interest does not affect the reliability of coordinate marking.</td>
</tr>
<tr>
<td>Tilley 1966</td>
<td>100 films, 3 methods, 10 times, 1 examiner</td>
<td>Intrinsic variation was found to be approximately 1 mm with a SD of 0.5 mm. Comparison of sacral base values was r = 0.979, 0.97 and 0.99 (p &lt; 0.01)</td>
</tr>
<tr>
<td>Troyanovich et al, 1999</td>
<td>30 films, 3 examiners</td>
<td>Intra-examiner: horizontal base angle ICC (0.72-0.94), lumbodorsal angle ICC (0.90-0.96); lumbosacral angle ICC (0.84-0.96), &amp; thoracic Tz ICC (0.95-0.97). Inter-examiner ICCs ranged 0.71 to 0.97.</td>
</tr>
</tbody>
</table>
Table 8. Lateral Lumbar Reliability

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen 1999</td>
<td>16 subjects, 3 films each, 3 observers, 2 occasions, Cobb L1-L5, L1-S1, Centroid method.</td>
<td>“Correlation coefficients of lumbar lordosis between the two methods ranged from 0.589 to 0.772 with participants standing upright (all P &lt; 0.05). Interobserver reliability coefficients were 0.903 for vertebral centroid measurement of lumbar lordosis, 0.826 for Cobb (L1-L5), and 0.784 for Cobb (L1-S1). Introbserver r greater than 0.9. The vertebral centroid measurement of lumbar lordosis showed the smallest mean absolute differences between any two observers’ measurements (&lt; 1.7º).”</td>
</tr>
<tr>
<td>Chernukha et al, 1998</td>
<td>199 supine lumbar radiographs, 3 observers, Cobb L1-S1, TRALL.</td>
<td>Spearman-Brown coefficients for parallel measurements obtained by analysis of variance for repeated measurements were .99 for each rater regardless of which method was used. Intramethod and interrater variability for TRALL was not significantly different than that for Cobb.</td>
</tr>
<tr>
<td>Frobin W et al, 1997</td>
<td>892 films, 2 examiners</td>
<td>Relative measurement error in vertebral height = 2.2%; for a vertebra of 30 mm height this corresponds to an error of approximately 0.7 mm. error in sagittal plane displacement amounts to 0.015 (measured in units of mean vertebral depth); for a vertebra of 35 mm depth this corresponds to an error of 0.5 mm. error in disc height amounts to 4.15%; for a disc of 10 mm height this corresponds to approximately 0.5 mm.</td>
</tr>
<tr>
<td>Gillian et al, 1994</td>
<td>15 films, 2 radiologists</td>
<td>The ICC’s for intrater reliability for radiological measurements were 0.92 and 0.95 for the sacral angle and 0.98 for the 2 measurements of pelvic angle. Intertester reliability were 0.86 and 0.88.</td>
</tr>
<tr>
<td>Harrison DE et al, 2001</td>
<td>30 films, 3 examiners</td>
<td>Inter- &amp; intra-examiner ICCs &gt; 0.83 for all segmental and global angles. mean absolute differences of observers' measurements were small (0.6º -2.0º ).</td>
</tr>
<tr>
<td>Pfeifer et al, 2003</td>
<td>45 films,</td>
<td>Measurement of intervertebral space height and sagittal translation: DCRA appears to be more reliable than CALSM.</td>
</tr>
<tr>
<td>Phillips et al 1986</td>
<td>99 films, 4 examiners recording each or 56 variables. Examiners were not experienced at all variables.</td>
<td>Although 56 variables were recorded, many contained no numerical measurement. Cronbach’s Alpha used to express reliability, no ICC’s and no standard errors of measurement were reported. 16/56 variables had agreement in the fair to moderate range (.6-.799) and 6/56 (short leg, sacral base, Ferguson’s gravity line, spondylolisthesis, spondylolysis, lumbarization) were in the excellent range (.8-1.0).</td>
</tr>
<tr>
<td>Polly et al, 1998</td>
<td>60 films, 3 examiners, 4 different techniques, 2 occasions</td>
<td>Measured magnitude of lordosis 4 ways: L1-L5, L1-S1, T12-L5 and T12-S1. All intraclass correlation coefficients were within the range from 0.83 – 0.96. Interobserver variability ranged from 0.81-0.92. Interrater reliability was consistently highest for the measurement of L1-L5.</td>
</tr>
<tr>
<td>Saraste H et al, 1985</td>
<td>12+170 films, 2 examiners</td>
<td>Radiographic evaluation of vertebral slipping and lumbosacral lordosis is equally reliable in the recumbent and standing positions.</td>
</tr>
<tr>
<td>Schuler TC et al, 2004</td>
<td>10 films, 12 examiners</td>
<td>Segmental lordosis at L4-5 &amp; L5-S: Cobb &amp; posterior body technique are least variable measurement.</td>
</tr>
<tr>
<td>Seel et al, 2005</td>
<td>24 films, 4 observers, 2 occasions, vertebral endplate cobb angles for fracture kyphosis measurement.</td>
<td>Intraclass coefficients were most consistent for method 2 (ρ = 0.856-0.976). Method 3 produced the lowest intraclass coefficients overall in our series (ρ = 0.846-0.919). A high level of intraobserver agreement was maintained when all results were pooled with respect to each observer. Each observer achieved 99% reproducibility. Method 2 (ICC = 0.95, CI = 0.926-0.967) had the best overall interobserver reliability. All three methods were well above the threshold of &gt;0.8.</td>
</tr>
<tr>
<td>Shaffer WO et al, 1990</td>
<td>132 films-2 raters, 750 films-1 rater, 58 films-2 raters</td>
<td>High consistency &amp; accuracy indices do not ensure acceptable false-positive &amp; false-negative rates. Using roentgenograms as a basis for diagnosing instability often can lead to errors in classification. This is less so when observed translations are &gt; (± 5 ± mm) on roentgenograms that are relatively clear, with little obliquity, &amp; concomitant motions are minimal.</td>
</tr>
<tr>
<td>Tibrewal et al, 1985</td>
<td>11 no pain 12 months, 10 with IVD disorder,</td>
<td>Intraobserver error (5 IVD’s, one radiograph, five times, 2 times) showed a maximum difference of 0.7 mm from the mean of five readings in 50 sets of measurements. Interobserver error (2 observers all films) showed a maximum mean difference between observers of 0.75 mm at the L5-S1 level.</td>
</tr>
<tr>
<td>Trojanovic h et al, 1998</td>
<td>30 films, 3 examiners</td>
<td>Intra-examiner ICC: only T12-L1 interssegmental measure &lt; 0.70. Inter-examiner ICC: for manual and computer-aided digitizing examiners: L1-5ARA 0.96; 0.84 for arcuate angle; 0.82 for Ferguson's angle; 0.88 for Cobb angle; 1.00 for Tz translation; &amp; 0.65, 0.73, 0.74, 0.75, 0.89 and 0.81 for segmental angles T12-L1, L5-S1.</td>
</tr>
<tr>
<td>Trojanovic h et al, 1995</td>
<td>30 films, 3 examiners</td>
<td>Except arcuate angle, all segmental &amp; global angle intra- &amp; inter-examiner ICCs &gt; 0.78.</td>
</tr>
<tr>
<td>Wilke et al, 2006</td>
<td>16 discs. X-rayed and measured grossly. Measurements were done by 2 observers.</td>
<td>The validation of the new radiographic grading system revealed a substantial agreement between the radiographic and the macroscopic overall degree of degeneration (Kappa=0.714, 95% CL: 0.587– 0.841). The interobserver agreement was substantial for all the three variables and for the overall degree of degeneration (Kappa=0.787, 95% CL: 0.702–0.872).</td>
</tr>
</tbody>
</table>
### Table 9. Lumbar Flexion/extension Reliability

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films, Examiners</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cakir B, et al 2006</td>
<td>24 films, 3 examiners, 2 methods</td>
<td>Inter examiner reliability: +/- 4° 95% confidence interval. Mean differences of observer measurements for intra examiner and inter = 1° or less</td>
</tr>
<tr>
<td>Fritz et al, 2005</td>
<td>49 flex. films 49 ext. films</td>
<td>Intraclass correlative coefficients for the various variables measured ranged from 0.84 to 0.99 for translation values, and 0.81 to 0.96 for angular measures.</td>
</tr>
<tr>
<td>Frobin W et al, 1997</td>
<td>892 lateral views of healthy male and female subjects</td>
<td>Small errors in measured disc height (0.7mm), vertebral height (0.5mm) and sagittal plane displacement (0.5mm)</td>
</tr>
<tr>
<td>Frobin W et al, 1996</td>
<td>61 films,</td>
<td>Error: angles less than 1.6° &amp; translations 1.2 - 2.4% vertebral depth.</td>
</tr>
<tr>
<td>Harvey SB, Hukins DW, 1998</td>
<td>Biomechanics study</td>
<td>Lateral &amp; flexion &amp; Extension: The calculated centric provides a robust reference point for kinematic calculations.</td>
</tr>
<tr>
<td>Panjabi M et al, 1992</td>
<td>3 film pairs, 35 digitizations, 1 digitizer.</td>
<td>Error ranges (2 x SD) for the motion parameters were 1) rotation =±1.25 °; 2) translation of the inferior posterior vertebral body corner = ± 0.86°; and 3) coordinates for the center of rotation = ±/ - 4.3 mm. spinal level &amp; radiographic quality affected magnitude of errors in all motion parameters.</td>
</tr>
<tr>
<td>Penning et al, 2005</td>
<td>5 sets of films, 3 examiners, 5 occasions</td>
<td>SEM for linear measurements = 0.1 to 0.8, and 0.3 to 2.3 for angular measurements.</td>
</tr>
<tr>
<td>Putto, Tallroth et al, 1990</td>
<td>20 patients, 2 flexion films, 2 extension each</td>
<td>Extension/flexion films taken by two different methods. Fairly acceptable correlations between inter-observer and intraobserver variations (r = 0.52-0.96 and 0.66 to 0.99, respectively) was reported.</td>
</tr>
<tr>
<td>Tallroth K et al, 1994</td>
<td>30 films, 3 examiners</td>
<td>Highest intra-observer angular variations at L5-S1 level (1.6°, ±1.6°, max. 9 °), highest sagittal translation at L5-S1 level (0.6 mm, ±0.8 mm, max. 4 mm). Highest angular inter-observer variation at L5-S1 level (2.6°, ±2.3°, max. 11°), highest variation in sagittal translation at L4-L5 level (1.4 mm±1.2 mm, max. 6 mm). Mean intra-observer variation for L5 spondylolisthesis was 1.0 mm±0.9 mm, max. 5 mm) &amp; inter-observer variation 1.3 mm ±1.1 mm, max. 6 mm).</td>
</tr>
<tr>
<td>Teyhen DS et al, 2005</td>
<td>20 films, 1 examiner, intra and inter examiner reliability on fluoroscopic videos.</td>
<td>Lateral &amp; flexion digital fluoroscopic video: Intra-image ICC =0.99, &amp; SEM = 0.4-0.7°and 0.2-0.3 mm. Inter-image ICC = 0.88, &amp; SEM = 0.7-1.4° &amp; 0.4-0.7 mm.</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Films/Examin</td>
<td>Findings</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>Berthonnaud E et al, 2005</td>
<td>30 films, 4 examiners</td>
<td>ICC measured within observers was between 0.93-0.99, ICC between observers were 0.92-0.99.</td>
</tr>
<tr>
<td>Faro FD et al, 2004</td>
<td>50 films</td>
<td>Biomechanics: The fists on clavicles position for lateral radiograph acquisition has less negative shift in SVA, less compensatory posterior rotation of the pelvis. This position is more representative of a patient's functional balance.</td>
</tr>
<tr>
<td>Jackson et al, 1998</td>
<td>50 volunteers, 50 lumbar degeneration, 30 low grade L5-S1 isthmic spondy, 30 idiopathic or degenerative scoliosis</td>
<td>Interobserver reliability for sagittal spinopelvic parameters ranged from 0.77-0.99, (P &lt;0.05). Intraobserver reliability for the majority of sagittal spinopelvic parameters measurements was in the good to excellent range in each group.</td>
</tr>
<tr>
<td>Jackson et al, 2000</td>
<td>20 subjects 2 films each</td>
<td>The most reliable measurements were PRS1 (for pelvic morphology), PA and HASP (for pelvic balance), and PRL3 and PRL4 (for regional lumbopelvic lordosis) by the pelvic radius technique, with r ≥ 0.96 (P &lt; 0.0001 for all correlations). The reliability correlation coefficients for pelvic balance measurements ranged from 0.99 to 0.95, and those for spinal balance ranged from 0.97 to 0.40.</td>
</tr>
<tr>
<td>Jackson RP et al, 2003</td>
<td>150 films, 2 examiners</td>
<td>Mean slippage for patients was 30% (range, 11-85%), with 34 patients (45%) having Grade I slips, 32 (43%) having Grade II slips, &amp; 9 (12%) having Grade III &amp; IV slips. Mean measurements between patients &amp; volunteers were significantly different (P &lt; 0.01) for lumbar lordosis, pelvic lordosis, and lumbopelvic lordosis.</td>
</tr>
<tr>
<td>Kuklo et al, 2006</td>
<td>30 films, 2 examiners, 6 variables, 2 times by hand, 2 times digitally.</td>
<td>Only difference between 2 methods was for T2-T5 regional kyphosis: manual error 5.41 vs. 7.19 digital. Combined method errors for all variables were T5-T12 = 6-7, T2-T12 = 4-5, T10-L2 = 4-5, T12-S1 = 4.98-5.3, Sagittal balance C7-S1= 6-7mm. “Digital measurement showed decreased measurement variability (increased precision) for the majority of commonly used AIS parameters”. Both had small errors.</td>
</tr>
<tr>
<td>Plaugher et al, 1990</td>
<td>3 examiners, 20 subjects for inter-examiner of retrolisthesis and cervical lordosis (Cobb C1-C7 and C2-C7), 1 examiner for intra.</td>
<td>Intra- and inter-examiner reliability for cervical lordosis &amp; retrolisthesis were excellent &amp; low standard error Pearson's r = 0.89-0.97, p &lt; .001 for cervical lordosis &amp; Pearson's r = 0.74-0.90, p &lt; .001 for retrolisthesis.</td>
</tr>
<tr>
<td>Rajnics P et al, 2001</td>
<td>30 films, 2 examiners &amp; 10 films, 1 examiner, 10 times</td>
<td>Interobserver repeatability: variables are more repeatable (&lt; ±1.5°) when the operator is experienced. A less (&lt;±6.5°) repeatable measurement is T4-T12 kyphosis, due to poor contrast on radiographs of the upper thoracic vertebrae. Both AP &amp; lateral films on 30 subjects were used.</td>
</tr>
<tr>
<td>Rillardon L et al, 2003</td>
<td>100 films, 5 examiners</td>
<td>Manual measurements &amp; computerized measurements: intra-class ICCs from 0.82 to 0.96. Inter- and intra-observer variabilities were comparable for the measurement techniques for thoracic kyphosis, lumbar lordosis, pelvic index, pelvic tilt, and slope of the sacrum. Inter- and intra-observer variability was lower when the sagittal tilt was measured with the computer.</td>
</tr>
<tr>
<td>Vedantam R et al, 2000</td>
<td>80 films,</td>
<td>Biomechanical study: authors recommend positioning the arms at 30 degrees of forward flexion from the vertical.</td>
</tr>
<tr>
<td>Vialle R et al, 2005</td>
<td>300 films. Biomechanical study</td>
<td>Mean values were 60°, 10°for maximum lumbar lordosis, 41°±8.4° for sacral slope, 13°±6°for pelvic tilt, 55°±10.6° for pelvic incidence, and 10.3°±3.1° for T9 sagittal offset. Strong correlation of sacral slope and the pelvic incidence (r = 0.8); for maximum lumbar lordosis &amp; sacral slope (r = 0.86); for pelvic incidence &amp; pelvic tilt (r = 0.66); between maximum lumbar lordosis &amp; pelvic incidence, pelvic tilt, and maximum thoracic kyphosis (r = 0.9); between pelvic incidence &amp; T9 sagittal offset, sacral slope, pelvic tilt, maximum lumbar lordosis, &amp; thoracic kyphosis (r = 0.98).</td>
</tr>
<tr>
<td>Ylikoski et al, 1990</td>
<td>30 lateral films</td>
<td>In measuring vertebral body height, the interobserver error of measurement (SD) was 3.2 and the intraobserver, 2.6 degrees. For the intervertebral disc height the interobserver error was 2.4 and the intraobserver, 1.8 degrees. These angles were transformed into height to length ratios.</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Films/Examin</td>
<td>Findings</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hamberg J et al, 1993</td>
<td>20 films (mounted phantom), 4 examiners, measured 3 times</td>
<td>Lateral: two methods &amp; x-ray measurements showed high reliability, hypothesis of a more posterior tilted pelvis in the new method was confirmed. Pearson’s correlation coefficients: length measurements = 0.81–0.98 (P &lt; 0.0005), with fine tuning of contrast = 0.96 – 0.99 (P &lt; 0.0005). Angular measurements = 0.99-1.00 (P&lt;0.0005), linear measurements = 0.99-1.00 (P&lt;0.0005)—same with fine tuning the contrast.</td>
</tr>
<tr>
<td>Boniforti FG et al, 1997</td>
<td>60 films, 3 examiners</td>
<td>AP: errors acetabular index were E1 ±5º, E2 ± 5 º, and E3 ± 3.5º. Yamamuro's measurement of lateral femoral displacement was more reliable than the Hilgenreiner distance. Errors of indicators of pelvic alignment showed a correlation with the age of the infant; the quotient of pelvic rotation was more reliable after seven months of age (p &lt; 0.0001). Errors of symphysis os-ischium angle tended to increase with age &amp; index of pelvic tilt decreased with skeletal maturation (p = 0.002).</td>
</tr>
<tr>
<td>Plaugher et al, 1993</td>
<td>37 subjects, 2 films, 2 examiners, measures 1 hour or 18 days apart.</td>
<td>For radiographic of Gonstead pelvic line drawing: no statistically significant differences in any measurement.</td>
</tr>
</tbody>
</table>
Table 12. Lower Extremity Reliability (short leg analysis)

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Films/Examin</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarke 1972</td>
<td>50 films</td>
<td>Skeleton positioned for initial establishment of face validity showed an accuracy of 3 mm at 100 cm tube film distance. Palpation of iliac crests was only accurate in 16/50 subjects within 5 mm, while 20/50 were accurate within 5 mm when using the tape measure method.</td>
</tr>
<tr>
<td>Fann et al, 1999</td>
<td>52 films, 4 raters, 2 occasions</td>
<td>Measured unlevelness with line of eburnation and the intersulcate line. Interrater correlation coefficients for the line of eburnation ranged from 0.82 to 0.9 and from 0.90 to 0.92 for the intersulcate method. Intrarater correlation coefficient was 0.81 to 0.84 for the line of eburnation and from 0.93 to 0.95.</td>
</tr>
<tr>
<td>Friberg et al, 1983</td>
<td>789 pain patients, 359 symptom free</td>
<td>Repeatability: 25 subjects repeat test/measurement and 5 to three times at 1-30 month intervals. Also 30 persons re-examined with a lift exactly the same size of the pre-measured lift. The mean error in all these repeated measurements was 0.6 mm, and it never exceeded 2 mm. Only 8% of all subjects had equal leg lengths.</td>
</tr>
<tr>
<td>Friberg 1985</td>
<td>20 films, 2 occasions</td>
<td>Mean error of measurement was 0.6 mm (range 0-2.0 mm). The second film was taken with a lift under the foot. Radiation doses were low.</td>
</tr>
<tr>
<td>Giles, 1981</td>
<td>AP Pelvic</td>
<td>Leg length inequality: 1.12mm ± 0.92.</td>
</tr>
<tr>
<td>Gofton and Trueman, 1971</td>
<td>AP Pelvic67 films</td>
<td>Leg length inequality: 1.44mm ± 1.06.</td>
</tr>
<tr>
<td>Greeneman et al, 1979</td>
<td>200 patients</td>
<td>This series falls within the margin of error of up to 1.5 mm of measurement.</td>
</tr>
<tr>
<td>Hamer OW et al, 2004</td>
<td>20 films, 4 examiners</td>
<td>Difference between the observers' angle measurements and the standard of reference was 0.4° distance measurements, mean discrepancies to the standard were 0.2 cm (femur) and 0.1 cm (tibia) for manual fine tuning &amp; 0.5 cm &amp; 0.7 cm, without manual correction</td>
</tr>
<tr>
<td>Kujala et al, 1987</td>
<td>121 w/knee injury, 20 w/out</td>
<td>Correlation coefficients for all rereadings were excellent (0.99-1.00), being 0.99 for the LLI (mm).</td>
</tr>
<tr>
<td>Leppilahti J et al, 1998</td>
<td>101 surgical films, 87 controls</td>
<td>The mean difference of measurements ranged from 0 to 2 mm (mean = 1 mm, SD = 0.8 mm: correlation of coefficient = 0.96)</td>
</tr>
<tr>
<td>Rozzanigo U et al, 2005</td>
<td>40 films, 2 examiners, 20 films, 5 examiners</td>
<td>Computer-aided evaluation of alignment &amp; articular orientation parameters of lower limbs is as accurate &amp; reliable as the traditional manual method, but is faster and allows better-quality images.</td>
</tr>
<tr>
<td>Rush et al, 1946</td>
<td>1000 subjects</td>
<td>Only 23% (N=230/1000) had equal femur head heights</td>
</tr>
<tr>
<td>Siu D et al, 1991</td>
<td>30 knee films, 4 examiners, 8 repositions</td>
<td>AP &amp; lateral: greatest error was random. Most angles were reproducible within ±1.3° or less at 95% confidence.</td>
</tr>
<tr>
<td>Stricker SJ, Faustgen JP, 1994</td>
<td>33 films, 1 examiners</td>
<td>Intraobserver SEMs &lt; 2.1 &amp; all ICCs &gt; 0.93.</td>
</tr>
<tr>
<td>Terry MA et al, 2005</td>
<td>16 films,4 examiners</td>
<td>Intraobserver (4 examiners &amp; 4 films) variance of direct slit scanogram measurement included intraclass ICC = 0.99, mean difference of 0.1 cm.</td>
</tr>
<tr>
<td>Wright JG et al, 1993</td>
<td>Biomechanical study</td>
<td>If limb was rotated no more than 10° from neutral, effect on apparent axial alignment was minimal &amp; measurement was reliable.</td>
</tr>
</tbody>
</table>
References


327.


IX. Reliability/Repeatability of Radiographic Positioning

RECOMMENDATION
Radiographic patient positioning procedures for spinal and lower extremity x-rays has been subjected to a large volume of inter and intra examiner reliability studies. The majority of these studies have found that an examiner(s) positioning of a patient is in the excellent reliability range and is not influenced by different examiners on the initial versus repeat radiographic study. However, the initial and follow-up radiographic positioning procedure should be clearly stipulated and followed. When a systematic procedure for radiographic positioning is followed, patient positioning does not cause significant errors and can be readily used for the clinical evaluation of spinal subluxation by chiropractic clinicians.

Supporting Evidence: Reliability Studies Class 1 and 2.

PCCRP Evidence Grade: Reliability Studies = a and b.

Introduction
In previous sections of this document, it was referenced that a sub-group of DACBRs and academics have made considerable assertions that x-ray analysis in clinical chiropractic practice is unreliable, invalid, and should not be routinely used to determine specific spinal treatment interventions.1-10 In this current section, we will investigate two more such claims promulgated by these groups:1-10

1. Radiographic positioning is not repeatable,
2. Variations in x-ray positioning simulate subluxation or correction.

The repeatability of x-ray positioning procedures is an important topic to understand as it relates to the ability to measure the 6 types of spinal subluxations (see Section V) and their response to chiropractic treatment interventions. The debate regarding radiographic positioning procedures is not unique to chiropractic. In terms of scoliosis evaluation on the AP full spine radiograph, Capasso et al11 discussed 4 groups of ‘theoretical grounds’ that may cause errors in the measurement of thoracic scoliosis:

A. Errors in taking a radiograph,
B. Errors intrinsic to the measurement method,
C. Errors due to anatomical deformity of the vertebra,
D. Observer errors in the measurement technique.

We note that B and D above were comprehensively reviewed in Section VIII. Capasso et al11 presented some available data on full spine positioning errors and consequent scoliosis measurement effects and offered solutions to minimize these; including a precise, supervised positioning protocol. We provide a discussion of the references utilized by Cappaso et al11 in Table 3 for thoroughness. However, the review by Cappaso et al11 only applies to scoliosis evaluation.

In addition to reviewing the literature on x-ray positioning reliability of scoliosis deformities, the current expert panel provides an exhaustive literature review of each radiographic spinal view. Our literature search identified 57 separate studies that have evaluated...
the test retest reliability of radiographic positioning procedures utilizing multiple examiners, exposures, and subjects.  

The literature presented below is in strong opposition to the opinions professed by several authors in the chiropractic literature. In the chiropractic literature, multiple articles and/or textbooks were identified, where the opinion was presented that Chiropractic and general x-ray procedures are not reproducible to the extent needed for identification of subluxation correction. Problematically, none of these sources present data on the test retest reliability of x-ray positioning procedures. These sources either offered Class V (expert opinion) evidence as support for the non reproducibility of x-ray positioning or they referenced another source which offered its author(s) Class V evidence with no supporting data.

For an example of this Class V referencing, Peterson and Hsu state, “Patient positioning also impacts on spinal curve analysis, particularly in the cervical spine where slight alterations in flexion or extension of the head can significantly change the cervical curve.” Surprisingly, when one looks at Peterson and Hsu’s reference citations, it is found that neither of these sources present any original data on the topic of the reliability of x-ray positioning procedures.

While the topic of postural effects on the cervical curve is important to delineate, to offer generalized criticisms without data, indicates the intent of the authors is to invalidate chiropractic radiographic assessment of subluxation instead of to improve upon it or understand it. In contrast, there are two sources that have quantified the effect that slight head extension has on the cervical curvature of subjects with an initial neutral lateral cervical radiograph. These two studies have found the average increased extension angle of the skull on a post-x-ray has a net increase in cervical lordosis of one half the skull extension value. In other words, a 10° skull extension on the post treatment intervention x-ray will increase the cervical lordosis by 5°.

To compile our comprehensive review, we performed literature searches in Index Medicus, CINAHL, and Mantis locating radiographic positioning repeatability studies from different fields in healthcare. Of interest, besides Medical Doctors (MD’s) and Chiropractors (DC’s) interest in radiographic positioning, Orthodontists, have studied head and lateral cervical radiographic positioning.

While MDs and DCs are interested in spinal alignment, segmental instability, scoliosis, thoracic kyphosis deformity, etc., Orthodontists are interested in the alignment of the skull bones and cervical vertebrae before and after (1) braces have moved teeth to new positions in the jaw and (2) the TMJ is aligned with orthotic devices inside the mouth.

It is the PCCRP panels position that these 57 reliability studies, with data on radiographic positioning, supersedes the popular Class V evidence provided by the sub-group of DACBRs and academics on this topic.

The organization of this section will be presented into tables of different regions. Tables 1-6 separate these 57 radiographic repeatability studies into 1) radiographic repeatability of the head and AP cervical views, (2) radiographic repeatability of the lateral cervical view, (3) radiographic repeatability of the thoracic spine, (4) radiographic repeatability of the lumbar spine, (5) radiographic repeatability of the pelvic region, and (6) radiographic repeatability of full spine views.

Besides being systematic, the arrangement of this data into tables of different regions will enable the interested reader to find studies for his/her specific interest. Especially, the ease of locating certain studies will save time and effort for clinicians and researchers.
**Table 1. X-Ray Positioning of the Head Region (n=15).**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooke &amp; Wei, 1988</td>
<td>217 laterals of 12 yr olds.</td>
<td>Reproducibility: same-day repeat radiographs recorded with ear posts &amp; with a mirror (after 4-10 minutes and 1-2 hours) = 1.9°.</td>
</tr>
<tr>
<td>Cooke 1990</td>
<td>Lateral: 30 lateral cervical with 5 year study.</td>
<td>Method error: 1.9° after 1-2 hours, 2.3° after 3-6 months, &amp; 3° after 5 years. SD (SN/vertical angulation) was 2.6° after 1-2 hours, 3.2° after 3-6 months, &amp; 4.2° after 5 years.</td>
</tr>
<tr>
<td>Cooke &amp; Wei, 1991</td>
<td>Lateral: 32 re-measured &amp; re-digitized.</td>
<td>Measures with most landmarks in the mid-sagittal plane showed the least increase in percentage error. error % was found to be doubled, on measurements on the retaken radiographs.</td>
</tr>
<tr>
<td>Foster et al, 1981</td>
<td>9 lateral x-rays, minimum 2-weeks apart.</td>
<td>Mean Differences: 3°-4.8° for angular measurements. X-ray positioning errors were smaller the mean error of the measurement method used.</td>
</tr>
<tr>
<td>Houston et al, 1986</td>
<td>24 subjects 2 lateral x-rays each on same occasion.</td>
<td>Analysis of variance showed small, inconsistent, non-statistically significant differences in several distances and angles on repeat lateral skull-cervical spine radiographs.</td>
</tr>
<tr>
<td>Huggare 1989</td>
<td>AP Cervical (2) &amp; Photos, 1 week delay.</td>
<td>Reproducibility: craniocvertical angle was 1.2°, craniocervical angle 0.9°, &amp; cervicohorizontal angle 1.5°</td>
</tr>
<tr>
<td>Kantor et al, 1993</td>
<td>54 pairs of cephalometric x-rays.</td>
<td>No statistically significant changes in 2 cranial &amp; 4 maxillary landmarks; results suggest that patient positioning is not a major contributor to the error of cephalometric methods.</td>
</tr>
<tr>
<td>Luyk et al, 1986</td>
<td>lateral cephalometric: 3 and 6 films were taken for each patient.</td>
<td>Neutral Head Posture (NHP) was not as reproducible as has been suggested by others. Reasons were examined, &amp; new proposals made concerning a rational approach to cephalometric radiographs.</td>
</tr>
<tr>
<td>Peng &amp; Cooke, 1999</td>
<td>Lateral: 20 Chinese at 12 yrs &amp; 27 yrs.</td>
<td>Reproducibility: after 15 years = 2.2°, after 5-year = 3.0° &amp; 5-10 minutes reproducibility = 1.9°. After 15 years variance of NHP (4.8°) remains significantly less than variance of intracranial reference planes to vertical (25°-36°). Cephalometric analyses based on natural head posture therefore remain valid over time.</td>
</tr>
<tr>
<td>Siersbaek-Nielsen &amp; Solow, 1982</td>
<td>30 orthodontic patients, 2 occasions 1-35 days apart, 3 examiners.</td>
<td>Error: whole group was 2.3° for head position in relation to true vertical (NSL/VER), 3.1° for cervical inclination (OPT/HOR), and 3.4° for craniocervical angulation (NSL/OPT).</td>
</tr>
<tr>
<td>Solow &amp; Siersbaek-Nielsen, 1986</td>
<td>43 NHP Cephalometric films on two occasions; 2.7 years apart.</td>
<td>Changes in the conventional measures of head posture—the craniocvertical angles--during the observation period showed no associations with growth changes in craniofacial morphology and was stable over time.</td>
</tr>
<tr>
<td>Spolyar 1987</td>
<td>20 subjects, 2 laterals &amp; PA Skull by different examiners.</td>
<td>Error: 1.7mm mean error (0.5mm-6.2mm) for distances, 1.59° mean error (0°-5.23°) for angles, and 3/20 had no measurable change.</td>
</tr>
<tr>
<td>Tsang &amp; Cooke, 1999</td>
<td>2 replicated sets of lateral cephalograms of 30 skulls.</td>
<td>15 angular &amp; 1 linear measurements were obtained from both methods; All, except one, cephalometric measurement showed significant differences between the two methods (P &lt; 0.0001). Error: DigiGraph Workstation ranged from 7 to 70 per cent, while that of radiographic tracings was less than 2 per cent.</td>
</tr>
<tr>
<td>Tng et al, 1994</td>
<td>30 skulls, 2 films each.</td>
<td>SD of Errors: skeletal angles 0.9-1.8°, except ANB was only 0.4° &amp; dental angles ranged from 3.2-5.8°.</td>
</tr>
<tr>
<td>Zappa et al, 1993</td>
<td>2 sets of 30 radiographs.</td>
<td>Difference in the measuring error of the system &amp; in the angular errors at time points 0, 6, &amp; 12 months could not be detected.</td>
</tr>
</tbody>
</table>
Table 2.
X-ray Positioning of the AP and Lateral Cervical (n=15).

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armijo-Olivo et al, 2006</td>
<td>Lateral head &amp; neck: 68 subjects, 2 x-rays</td>
<td>Self Balance Position compared to Frankfurt position: No changes related to gender and age were found.</td>
</tr>
<tr>
<td>Gore 2001</td>
<td>Lateral: 159 subjects, 10 yr follow-up</td>
<td>Means &amp; SD of Cervical lordosis were the same: Pain is more likely to develop in persons with degenerative changes at C6-C7.</td>
</tr>
<tr>
<td>Harrison et al, 1994</td>
<td>Lateral: 35 control subjects, x-rays at 14 weeks apart</td>
<td>No statistically significant changes existed between pre- and post-tests for the control group except in C6-7 relative rotation angle.</td>
</tr>
<tr>
<td>Harrison et al, 2002</td>
<td>Lateral: 24 controls, x-ray at 8 months</td>
<td>No change in the pain VAS ratings &amp; no statistically significant change in segmental or global radiographic alignment.</td>
</tr>
<tr>
<td>Harrison et al, 2003a</td>
<td>Review of literature on Lateral Cervical and AP Cervical views</td>
<td>48 out of 50 measurements: differences between initial &amp; follow-up radiographs are less than 1.0° and 2.0 mm. Posture, radiographic positioning, and radiographic line drawing are highly reliable.</td>
</tr>
<tr>
<td>Harrison et al, 2003b</td>
<td>Lateral Cervical: 33 controls, x-rayed at 8.5 months</td>
<td>No change in VAS pain ratings &amp; no statistical significant change in segmental or global cervical alignment (difference in all angle mean values &lt; 1.3°).</td>
</tr>
<tr>
<td>Harrison et al, 2004</td>
<td>AP Cervical: 26 control subjects, x-rays 1 yr</td>
<td>No significant differences were found in the control group subjects' pain scores and AP radiographic measurements.</td>
</tr>
<tr>
<td>Hellsing et al, 1987</td>
<td>14 lateral x-rays, 8 months apart</td>
<td>No statistically significant differences were found for measurements of cervical spine curvature.</td>
</tr>
<tr>
<td>Huggare 1993</td>
<td>Lateral: 33 subjects, 2 cephalometric radiographs each</td>
<td>Reproducibility: craniovertical, craniocervical &amp; cervicohorizontal relationships comparable with previous results with mirror method. Standing to a sitting position in the cephalostat without change in craniovertical, craniocervical or cervicohorizontal relationships.</td>
</tr>
<tr>
<td>Jackson et al, 2000</td>
<td>AP nasium &amp; lateral; 38 subjects, 2 sets of x-rays within 4 hrs</td>
<td>ICCs = 0.94-0.98, error for upper angle and lower angles less than 1°, SEM ≈ 0.7° for lower angle.</td>
</tr>
<tr>
<td>Ordway et al, 1997</td>
<td>Lateral: 20 subjects, concurrent validity C-ROM device, 3Space &amp; lateral x-ray</td>
<td>End-range sagittal cervical flexion, extension, protrusion, and retraction measured simultaneously with 3 devices. Protrusion and retraction can be measured reliably with all three methods studied, but without measurement consistency between devices.</td>
</tr>
<tr>
<td>Rochester &amp; Owens, 1996</td>
<td>AP Nasion: 20 x-rays analyzed for the amount of y-axis rotation as artifact.</td>
<td>Validity study: atlas laterality artifact = 0.0 degrees artifact from the average of 0.56 degrees patient rotational positioning error that was demonstrated on 20 randomly selected nasium views. An artifact in atlas laterality measurement of 0.5 degrees was not detected until the rotational patient positioning error exceeded 1.75 degrees with a tube angle of 25 degrees.</td>
</tr>
<tr>
<td>Sandham 1988</td>
<td>12 lateral cervical skull films taken 1 hour apart.</td>
<td>Six different measures of cervical spine and head position. No statistically significant differences were noted among any of the variables between the 1st and repeat lateral cervical radiograph.</td>
</tr>
<tr>
<td>Shrout et al, 1993</td>
<td>Lateral: 61 subjects, 19 re-x-rayed at 0, 6, 12, 18, &amp; 24 months.</td>
<td>Angular alignment error was less than 2 degrees total angular error (1.3-2.4 degrees, 95% confidence intervals).</td>
</tr>
</tbody>
</table>
### Table 3.

**X-Ray Positioning of the Thoracic Region, AP Full Spine, & Lateral Thoracic (n=10).**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunnel et al, 1988</td>
<td>Review article on AP Full spine scoliosis deformities.</td>
<td>Class V (opinion) evidence that radiographic positioning affects the magnitude of scoliosis curve values. No supporting data.</td>
</tr>
<tr>
<td>Capasso et al, 1992</td>
<td>Review article on AP Full spine scoliosis deformities.</td>
<td>Stated, “Small positional changes of the patient may result in significant errors in curve evaluation. A standard AP free-standing view may show a difference of up to 17° when compared with a radiograph taken with a special device.” Capasso et al misrepresented several studies and thus have inaccurate conclusions. See below for details under specific study.</td>
</tr>
<tr>
<td>Dawson et al, 1978</td>
<td>60 scoliosis subjects, AP full spine vs. scoliosis chariot (SC), same day. 14 subjects had 2, 5 minute repeated SC views.</td>
<td>Average differences in Cobb angle between the AP full spine and SC view of 3.4°-7.5° (increased as curve magnitude increased). Difference in 2 repeated SC views: All measured curves were within ± 3°. Authors concluded that SC views for scoliosis were more repeatable. However, repeated AP full spine views were not performed.</td>
</tr>
<tr>
<td>Desmet et al, 1982</td>
<td>78 scoliosis subjects, AP full spine vs. PA full spine views, 5-15 minutes apart.</td>
<td>Strong correlation between curve measures on AP vs. PA full spine films, $r = .960$. PA view had mean increased curves: 1.71°. In 5/128 curves a 9°-13° increase on PA, 19/128 curves 6°-8° increase on PA, in 4/128 curves a 6°-8° decrease on PA film. Difference is due to projection of endplates on PA vs. AP films.</td>
</tr>
<tr>
<td>Kohlmaier et al, 1995</td>
<td>AP FS: 100 subjects, 2 x-rays, neutral &amp; positioning device.</td>
<td>Balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards.</td>
</tr>
<tr>
<td>Milne &amp; Williamson, 1983</td>
<td>261 repeated Lateral thoracic x-rays, 5 years apart.</td>
<td>No statically significant differences in radiographic measurement of thoracic kyphosis at average 5 year follow-up.</td>
</tr>
<tr>
<td>Pruijs et al, 1994</td>
<td>PA full spine, 10 scoliosis subjects, 3 x-rays each. Cobb on each film. Note: this is one of the only studies to take repeat AP/PA full spine films in vivo in the same manner &amp; view with no device.</td>
<td>Difference 1 and 2: -0.6° ± 2.6°, standard error 1.9°, correlation=.99 Difference 2 and 3: 0.0° ± 3.5°, standard error 1.2°, correlation=.98 Difference 1 and 3: 0.6° ± 3.2°, standard error 1.1°, correlation=.98 Whole group 1,2,3: standard error = 2.2°. “Apparently, subjects with established spinal deformity assume a more or less similar position each time they are subjected to x-ray examination.”</td>
</tr>
<tr>
<td>Sevastikoglou et al, 1969</td>
<td>2 Scoliosis skeletons, 17 views: neutral, rotation up to 10° left and right and 5 cm elevation or depression of tube height. 2 examiners, Cobb &amp; Ferguson.</td>
<td>Little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson’s method and 2.06° ± 1.09° for Cobb’s method. This was misrepresented by Capasso et al.¹¹</td>
</tr>
<tr>
<td>Singer et al, 1982</td>
<td>Lateral: 22 cases with films in vivo, &amp; post-mortem films.</td>
<td>In vivo &amp; in vitro measurements strongly correlated (Cobb angle $r = 0.95$, curvature $r = 0.78$). Trends decreased in Cobb angle (1.3%, -2.6%) &amp; increased slightly in curvature (10.7 mm, 4.1%).</td>
</tr>
<tr>
<td>Stagnara et al, 1982</td>
<td>Lateral: subjects at 5 yrs &amp; 10 yrs.</td>
<td>X-ray measurements of kyphosis and lordosis are constant to within a few degrees provided the position is clearly stipulated.</td>
</tr>
</tbody>
</table>
### Table 4.
**X-Ray Positioning of the Lumbar Region (n=5).**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harrison et al, 2002</td>
<td>Lateral: 30 controls, x-ray follow-up 9 months.</td>
<td>Pain scales and radiographic measurements did not change in the control subjects.</td>
</tr>
<tr>
<td>Harrison et al, 2003</td>
<td>Lateral Lumbar &amp; APL: 6 control groups, x-rayed at 11 months.</td>
<td>48 out of 50 measurements: differences between initial &amp; follow-up radiographs are less than 1° and 2 mm. Posture, radiographic positioning, and radiographic line drawing are highly reliable.</td>
</tr>
<tr>
<td>Harrison et al, 2005</td>
<td>APL: 23 controls, follow-up x-ray at 37.5 weeks.</td>
<td>No significant radiographic and NRS differences were found, except in trunk-list displacement of T12 to S1, worsened 2.4 mm.</td>
</tr>
<tr>
<td>Saraste et al, 1985</td>
<td>Lateral: 125 subjects, recumbent &amp; standing x-rays.</td>
<td>Differences between radiographs of spondylolytic patients in recumbent &amp; standing positions were analyzed with respect to vertebral slipping and lumbo-sacral lordosis. Only minor projectional &amp; inter-observer measurement errors in variables describing vertebral size and lumbo-sacral lordosis.</td>
</tr>
<tr>
<td>Stagnara at al, 1982</td>
<td>Lateral: subjects at 5 yrs &amp; 10 yrs.</td>
<td>X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees provided the position is clearly stipulated.</td>
</tr>
</tbody>
</table>

### Table 5.
**X-Ray Positioning of the Pelvic Region (n=7).**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
</table>
| Beal 1950             | AP Pelvis, 5 subjects, 3 x-rays by 3 different examiners. | Femur head height differences: 1-3mm  
Rotation of pubic symphysis relative to midline: 3mm-11mm.                                      |
| Clark 1972            | AP Femur/Pelvis, 1 examiner, 50 subjects, repeated x-ray with a lift in and multiple x-rays of a skeleton with 15 degrees of rotation and 5 cm of tube height changes. | AP Femur head height differences did not vary more than ± 3mm of the known short leg discrepancy of 20mm on repeated x-rays of the skeleton. Repeat femur head x-rays of the subjects with the lifts in were accurate within ± 3mm using the original determination of the short leg measurement. Thus, positioning of the subject did not result in significant error and rotation up to 15 degrees and tube elevation up to 2.5 cm does not affect the measured displacement with this x-ray technique. |
| Friberg et al, 1985   | AP Pelvis, 20 subjects, 2 x-rays, 1-30 months apart. | Mean femur head height difference: 0.6mm with a range from 0mm-2mm.                                                                     |
| Friberg 1987          | AP Pelvis, 105 subjects, 2 x-rays, 3 weeks- 3 years apart. | Mean differences: anatomical leg length 0.7mm. In 46/105 repeat films pelvic rotation about gravity was measured. Mean differences: 0.9° (range 0°-3°) ± 0.8°. |
| Giles & Taylor, 1981  | AP Pelvis, 12 subjects, 2 x-rays same day. | On repeated pelvic x-rays with the ‘correct amount of lift in place’, the error between initial measures and repeated measures of leg length estimation was: 1.12mm ± 0.92mm. |
| Leppilahti et al, 1998 | AP Pelvis, 15 subjects, 2 x-rays, same occasion. | Leg length inequality on repeat films: 1mm (0-2mm range) ± 0.8mm. Correlation coefficient on repeat films = 0.96. |
| Plaugher et al, 1993  | AP: 37 Subjects re x-ray: 20 at 1hr and 17 at 18 days later. | Subject can be reliably positioned for repeat antero-posterior pelvic radiography for both 1 hr and 18-day intervals. |
Table 6.
X-Ray Positioning of the Full Spine (n=8).

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Radiographic View</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beck &amp; Killus 1973</td>
<td>Lateral full spine statistical model of healthy subjects.</td>
<td>“…several X-rays of the same individuals furnished reproducible results, even though they were taken years apart.”</td>
</tr>
<tr>
<td>Faro et al, 2004</td>
<td>Lateral: 50 patients in 2 different standing positions.</td>
<td>Fists on clavicles position has less negative shift in SVA, and in surgery patients less compensatory posterior rotation of the pelvis. This position is more representative of a patient's functional balance while still allowing adequate lateral radiographic visualization of the spine.</td>
</tr>
<tr>
<td>Horton et al, 2005</td>
<td>Lateral: 25 patients in 3 different standing positions.</td>
<td>Regional measures do not differ in the three positions, but global balance is anterior with 60° arm/shoulder position. Clinically, clavicle position may result in more accurate radiographic measures &amp; may minimize repeated radiograph exposures.</td>
</tr>
<tr>
<td>Jackson et al, 2000</td>
<td>Lateral: 20 volunteers &amp; 20 patients, 2 standing lateral radiographs, 66 months and 2 weeks apart, respectively.</td>
<td>Small variation in the thoracic kyphosis from T1-T12 was found between the 1st and follow-up x-ray with ranked correlation coefficients of $r = 0.81$ for volunteers and $r = 0.79$ for patients. Lumbar lordosis: ranked correlation coefficients of 0.93-0.96 for both patients and volunteers.</td>
</tr>
<tr>
<td>Jackson &amp; Hales, 2000</td>
<td>Lateral: 30 volunteers had 2nd radiograph 5-6 years later.</td>
<td>Measurement with least change was for pelvic morphology (PR-S1 angle); then length of the pelvic radius, pelvic alignment over the hips (pelvic angle), &amp; total lumbo-pelvic (PR-T12) &amp; lumbosacral (T12-S1) lordosis. Other longitudinal measurements, including those for thoracic kyphosis and spinal balance by a plumb line, showed slightly greater change.</td>
</tr>
<tr>
<td>Marks et al, 2003</td>
<td>Lateral: 15 subjects, 4 standing positions varying shoulder &amp; knee flexion &amp; over ground walking.</td>
<td>Measurement of sagittal vertical axis on shoulders flexed positions results in a sagittal vertical axis that is at least 3 to 4 cm more posterior than a sagittal vertical axis observed during a functional position. Subject repositioning resulted in an inter-trial variability of at least 0.8 cm in sagittal vertical axis, while variation as the subject held each standing posture had little contribution to overall error of measurement. Of the 4 positions, shoulder flexion (45 degrees) alone was the best position for a lateral radiograph due to minimal compromise to repeatability of sagittal vertical axis.</td>
</tr>
<tr>
<td>Van Royen et al, 1998</td>
<td>Lateral: one patient total ankylosis virtual SVA was constructed in 7 standing postures.</td>
<td>X-ray with video analysis: results of the study showed that SVA translations during standing radiographic analysis in a patient with a fixed spine depend on small changes in the hip, knee, and ankle joints.</td>
</tr>
<tr>
<td>Vedantam et al, 2000</td>
<td>Lateral: 40 patients with &amp; 40 without a previous spinal fusion, 2 positions.</td>
<td>1st radiograph with patient's arms raised horizontally forward at 90° flexion, &amp; 2nd with arms raised horizontally forward at 30° flexion at shoulder. No statistically significant difference in segmental and regional sagittal alignments. Patients had negative shift of SVA with 90° arm position.</td>
</tr>
</tbody>
</table>
References


Head Region


Lateral Cervical


AP/PA Thoracic or Full Spine AP/PA View


Lateral Thoracic


AP/PA Lumbar


Lateral Lumbar


AP Femur/Fergusson


Lateral Full Spine


X. Description and Efficacy of common Chiropractic radiographic views

RECOMMENDATION
The 19 common Chiropractic Radiographic views and the motion assessment procedures are indicated for the routine qualitative and/or quantitative assessment of the biomechanical components of vertebral subluxation. These radiographic views have reliability, validity, and clinical outcomes data that evidence their clinical utility in clinical chiropractic practice. When using these radiographic views and procedures, a baseline value of the mechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.


PCCRP Evidence Grade: Specific Grades will be given under each view.

Introduction
There are numerous spine radiographic views that are utilized by both Medical Doctors and Chiropractors. Some radiographic views are unique to the medical profession for locating pathologies and fractures and some are unique to the chiropractic profession for locating and measuring spinal subluxations.

The PCCRP Guideline Panel has determined a set of radiographic views that are utilized in different chiropractic technique methods and by Chiropractors in general, for the assessment of spinal subluxation. After listing these radiographic views, there will be a discussion of each views clinical utility by breaking the discussion of the literature into these topics:

- History of the view,
- Reliability of measurements for spinal subluxations,
- Reliability of patient positioning for the view,
- Validity of the particular view,
- Outcome studies using conservative chiropractic or other treatment methods.

Some of the publishing DACBRs and Chiropractic academics have stated that there is little or no evidence for radiographic biomechanical assessment of spinal subluxations. In addition to providing Level V (opinion) evidence, some DACBR’s, Chiropractic academics, and MCO’s often refer to ‘selective’ literature and often mis-represent certain studies.

For example, the 2001 study by Gore is often used to support the contention that radiography lacks predictive validity. Of interest, the study by Gore actually supports the predictive validity of spinal radiography, in as much as Gore found that cervical spine degenerative joint disease in the mid-lower cervical spine predicted which subjects (initially asymptomatic) developed cervico-genic symptoms at minimum 10-year follow-up. Gore did not report the cervical lordosis variables for subjects who did versus those who did not develop cervico-genic symptoms, instead he offered Level V evidence. Still, chiropractic advocates continue to use the study by Gore to claim the cervical lordosis lacks predictive validity.
As a last point to address, many Chiropractic academics use one-sided arguments in their push to limit the chiropractic clinician’s use of spinal radiography. For example, Whalen placed the burden of radiography validity on the practicing chiropractor and techniques when he stated, “The promoters of certain techniques who have positioned themselves reliant on x-ray, like the rest of us, are obligated to produce the evidence to show that it makes a difference either (a) in terms of increased risk from treatment that provides good benefit if the x-rays are not taken and/or (b) that taking the images makes any difference in outcome over treatment without the x-rays.”

However, it is the position of the PCCRP panel that because the majority of chiropractic clinicians use radiography (see Section III and IV) to determine contraindications to specific interventions, spinal subluxation type (as defined in Section V), and exact treatment intervention, then the burden of proof should be placed on those who would like to limit radiography in chiropractic. In other words, groups that would limit the chiropractic clinician’s use of spine radiography should be responsible for demonstrating that patient safety and outcomes are the same when radiography is not used compared to when it is used for specific chiropractic interventions for all possible patient presentations. Unfortunately, there is no evidence showing improved or equivalent outcomes when spinal radiography is not used in chiropractic clinical practice compared to when it is used. Therefore, the use of spinal radiography remains the standard of care in chiropractic clinical practice.

Radiographic assessments can be considered valid if they precisely reflect certain characteristics or they can accurately predict future outcomes or have strong correlation to a particular pain, disease, or health disorder. In truth, there is a plethora of information in the literature supporting radiography for assessment of spinal subluxations. We have decided to provide this evidence for the radiographic views utilized in different Chiropractic Techniques. We have placed chiropractic radiographic views into classifications by the region visualized on the film, i.e., cervical, thoracic, lumbar, pelvic, full spine, stress/bending films, and motion x-ray for trauma. These radiographic views include, but are not limited to:

A. Cervical Views
   1. AP Cervical/Cervico-Thoracic
   2. Nasium
   3. APOM
   4. Blair Protracto Views
   5. Vertex
   6. Base Posterior
   7. Lateral
   8. Sagittal Translation Stress/weighted View
   9. Flexion/extension

B. Thoracic Views
   10. AP
   11. Lateral

C. Lumbar Views
   12. AP
   13. Lateral
   14. Flexion/extension

D. Pelvic
   15. AP Fergusson
16. AP (short leg/femur head view)

E. Full Spine

17. AP

18. Lateral

19. Bending and/or stress films for the assessment of scoliosis or buckling

F. Motion X-ray for Trauma Evaluation.
References

A. Cervical Views

1. AP Cervical/Cervico-Thoracic

RECOMMENDATION

The AP Cervical or Cervico-Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II-V, Population Studies Class 2 and 4, Biomechanics, Reliability Studies Class 1 and 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The AP Cervical view provides better visualization of the upper thoracic and mid to lower cervical alignment. This projection also allows better visualization of any pathologies and anomalies that are present.

The AP Cervical projection is taken at a focal film distance of 40 inches with a 15 degree cephalad tube tilt. The central ray (CR) is directed through the mid cervical region or CR at T1 by CBP Technique in order to visualize the upper thoracic spine’s compensation to cervical posture. This view can be taken standing or seated using a stool or positioning chair. The patient is positioned with their back against the grid cabinet with the frontal plane of the thorax parallel to the cabinet. The positioning of the grid cabinet is to include C2 superiorly and at minimum T2-T3 inferiorly. (Figure 1).

Measurements are made on the AP Cervical view in millimeters and in degrees for disturbances of the vertical coronal alignment. (Figure 2).

Figure 1. AP cervicothoracic radiographs are obtained with the patient sitting/standing with his/her shoulders centered against the cabinet. A 10x12 in. cassette is generally used with central ray at the mid-lower cervicals and for visualization of the upper thoracic spine. If mid thoracic spine down to T6/7 is needed then it can be taken on a 7x17 in. cassette as depicted. This increased visualization of the upper thoracic spine is to see possible thoracic compensation due to cervical spine abnormalities. The patient positioning should be accomplished through small movements of the patient’s feet and NOT by altering the patient’s posture.
Many chiropractic techniques use AP cervical views, along with lateral cervical views, to determine the course of care for the patient. This determination includes patient positioning for the adjustment where the pre-manipulative force is applied, as well as what line of drive will take place. This adjustment is usually manual, but a hand-held instrument can substitute for the manual line of drive. These same techniques require that a post-treatment x-ray be obtained to validate, objectively, a successful course of treatment (i.e., reduction of head translation in millimeters, reduction in the CD or other angles, thus reduction of the subluxation misalignments and angle of lateral bending of T1-T3 compared to vertical).

### Reliability of Line Drawing Methodology

The measurements on the AP cervical view have been subjected to scrutiny by many within the chiropractic profession. In the medical literature, Cobb angle analysis has been the method of choice for measurement of levo- and dextro-scoliosis on anteroposterior radiographic views. In 1995 Skalli et al. evaluated the Y-axis rotations-methods of AP radiographs and they determined that the pedicle method of Drerup has high reliability.

In 2001, Janik et al. reported on a method to measure lateral flexion and axial rotation coupled motions on AP cervical radiographs. They studied these parameters on AP Cervical radiographs in two methods, one axial rotation of a C3 model and on radiographs of 30 subjects with 3 examiners, who evaluated the 30 radiographs twice. On the model, the method had an error of less than 0.75°. For lateral flexion, they reported ICCs > 0.86 (high range) and for axial rotation, they reported ICCs > 0.67 (good & high range).
Finally, chiropractic biophysics digitized radiographic mensuration analysis of the AP cervicothoracic view showed correlation coefficient values $>0.70$. These values are considered excellent for use in clinical and research operations.\textsuperscript{3,12,13}

### Reliability of Patient Positioning

Huggare\textsuperscript{7} performed a study analyzing neutral head posture on posterior to anterior radiographs using a sample population of twenty-two. Huggare concluded that “frontal head position is more accurately reproducible than the sagittal head position.”\textsuperscript{7} Harrison et al\textsuperscript{4} investigated the repeatability of AP cervical radiographic positioning and analysis in 23 control subjects with chronic neck pain. The mean follow-up time between repeat radiographs was 11.7 months and different examiners were used on initial versus follow-up radiographs. All angles and distances changed less than 1° or 1mm and all P-values were reported as not statistically significantly different (P$>0.05$).

### Diagnostic Capabilities

The AP cervical view demonstrates the best visualization of the lower six cervical vertebrae (especially vertebral bodies, Von Luschka joints, and spinous processes), the upper three thoracic vertebrae and ribs, medial border of the clavicles, lung apices, trachea, and neck muscles.\textsuperscript{14} Suspended expiration is also recommended during the x-ray processes.

### Validity

Investigations have found positive correlation and validity of the AP cervical radiographic alignment to the following health related conditions including:

1. Chronic neck pain duration and intensity,\textsuperscript{8}
2. Whiplash associated disorders (WAD),\textsuperscript{15}
3. Degenerative joint disorders of the mid and upper cervical spine.\textsuperscript{16}

In a retrospective examination of 335 AP cervical radiographs of patients screened for lateral head translations $\geq5$mm, Oakley and Harrison\textsuperscript{8} identified 176 (53%) patients with this AP cervical subluxation. Of these, 146 patients (67 male; 79 female) had head/neck complaints. Thirty-eight percent of neck pain patients (56/146) had left head shifts while 62% (90/146) had right head shifts. The typical pattern was an upper thoracic lateral flexion angle toward, and a mid-neck angle away from, the side of head lateral translation. Those with left head shifts suffered from pain longer but had smaller absolute mid-neck angles. Significant correlations existed between patient age and pain duration, pain duration and head translation distance, absolute head translation distance and age and absolute mid neck-angle and neck disability index (NDI) score.

In 1960, Zatzkin and Kveton\textsuperscript{15} reported the AP cervical spine radiographic findings of 25 men and 25 women involved in a motor vehicle accident (MVA) and compared their results to 35 normal controls (25 men & 10 women) with no history of trauma or symptoms related to the cervical spine. They found significant differences between the two groups in AP cervical radiographic alignment; where the whiplash group had AP cervical scoliosis present in 46% of subjects versus only 9% of the Control subjects.

Another investigation found conflicting results where the AP cervical alignment measurements did not correlate to acute and chronic neck pain.\textsuperscript{17} Yi-Kai et al concluded that AP cervical alignments are not different between 87 neck pain patients compared to 21 controls.
Problematically, acute (1 day duration) and chronic (4 years duration) neck pain subjects were lumped together by Yi-Kai et al\textsuperscript{17} in their analysis and no measurements of the AP cervical alignment were performed except the C1-C2 joint space alignment (this is discussed further under the APOM View). Therefore, the study by Yi-Kai et al\textsuperscript{17} has serious methodological flaws and does not apply to the alignment of the AP cervical radiographic view other than the C1-C2 left/right joint space.

**Biomechanical Validity**

There are several types of validity. Construct and predictive validity are applicable in clinical situations as just previously discussed, while a second type, we term “Biomechanical validity”. For this second type of validity, the clinician compares the spinal coupled motions on the AP cervical radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on AP cervical radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements and AP cervical radiographic patterns. In a series of original publications, reviews and texts, Harrison et al\textsuperscript{18-21} have outlined the cervical coupling movement for the head postures of:

1. Head axial rotation
2. Head lateral bending
3. Lateral Head Translations.

It is the consensus of the PCCRP panel that the quality of investigations finding a correlation between AP cervical radiographic alignment and the conditions in the above 3 categories is superior to the one negative correlation study. Thus, we conclude that the AP cervical radiographic alignment has positive correlation and validity for these 3 categories.

**Outcome Investigations**

**Level I studies**: No level I studies could be located.

**Level II studies**: Harrison et al\textsuperscript{4} reported on fifty-one patients, with chronic neck pain and lateral head translation posture (side shift), who received Mirror Image opposite postural exercises, drop table adjustments, and opposite postural traction. The treatment subjects were compared to a control group of twenty-six subjects with lateral head translation posture and chronic neck pain. Radiographic measurements and pain scales were compared at initial and follow-up for treatments subjects (at 12 weeks and 37 visits) and control subjects (at 50 weeks and no treatment). Radiographic subluxation of the AP cervical spine was used to determine treatment. No statistically significant changes were observed for control subjects’ pain and radiographic measurements, while treatment subjects showed statistically significant improvements in AP cervical radiographic measurements of head translation posture and pain.

**Level III studies**: No Level III studies could be located.
Level IV studies: Harrison, Harrison and Haas\textsuperscript{5} reported on AP cervical radiographic alignment, pain and disability improvements in 5 cases following CBP Mirror Image rehabilitative methods directed at reduction of AP cervical subluxations.

Oakley and Harrison\textsuperscript{9} reported on the successful reduction of AP cervical radiographic subluxations and consequent improvements in pain, disability, and health status following CBP Mirror Image rehabilitation of a 57 year old female with chronic, post-surgical, cervical spine pain and impairments.

Bolton and Bolton\textsuperscript{22} reported the successful management of 3 cases with acute cervical torticollis pain and impairments using the toggle recoil adjusting methods. The direction and side of the thrust was determined by AP radiographic alignment.

Moore\textsuperscript{23} described the management of a patient with upper crossed syndrome and cervicogenic headache using a multi-modal chiropractic approach including specific diversified adjustments to the cervical spine, myofascial release, and exercise. Importantly the alignment of the cervical spine on radiograph was an important determinant of treatment and improved alignment was found on follow-up.
References


2. Nasium Radiographic View

RECOMMENDATION

The AP Nasium Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I-V, Population Studies Class 2, Biomechanics, Reliability Studies Class 1 and 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = A, B, C, D, and Reliability, Biomechanics, Validity = a, and Population studies = b.

Introduction

The AP nasium (or just Nasium) upper cervical radiographic view was, in part, originated by A.A. Wernsing, DC in 1930.1,2 Wernsing’s standard set of X-rays included the scout AP, true lateral, scout lateral, true A-P, A-P 45, and a superior inferior view. These were used to perform accurate “True Plane Radiography.” He developed the first orthoprotractor instrument in the fall of 1934, which enabled him to measure the subluxation in degrees; however, Wernsing stated that he did not claim to measure the position of the atlas in fractions of a degree. A second orthoprotractor was later developed that made it unnecessary to draw lines on X-rays. He measured atlas laterality on the A-P true and the A-P 45 views. Atlanto-axial rotation was measured on the A-P and true lateral view.

This view can be taken standing or sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (Figure 1)

This view requires a little more work in equipment and positioning time compared to an AP open mouth or an AP cervical view. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40”, and precision head clamps with a centering glabella rod. Grostic was the first to add the precision head clamps and positioning chair for precise positioning in this radiographic view.3-7 A lateral cervical x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject’s facial features. This tilt and tube height is derived from the atlas plane line on the lateral cervical view. On the lateral view, a line through the atlas is compared to horizontal and given either an “S-Line” designation (1 SL = 10º) or is just measured in degrees. In upper cervical specific techniques, the “S-Line” is denoted S –5 to S5 depending on where the atlas sagittal line intersects the anterior skull structures.

Measurements are made on the nasium view in degrees with the use of templates and/or computer-aided digitization techniques. The skull is bisected using the edges of the parietal bones, while a line is drawn through the atlas (APL is drawn at the intersection of the inferior posterior ring and the lateral edges of the lateral masses). These two lines create the Upper Angle (UA). There are a few variations of creating a Lower Angle (LA), but in general it represents the
path of projected centers of mass or centers of the neural canal from C2 to C7. **Figure 2** illustrates some geometric lines drawn on the nasium view.

Many Chiropractic Techniques (termed Upper Cervical Techniques) use measurements on the Nasium view to determine the care of a patient.\textsuperscript{1-11} This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore, these techniques require that a post treatment nasium x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

**Figure 1 AB.** In A, a schematic showing the seated Nasium view with head clamps, glabella rod, tube tilt, tube height, and positioning chair. In B & C the standing Nasium radiographic view is shown with head clamps, glabella rod, tube tilt, tube height, etc. Typically the head would be slightly flexed to remove the teeth projection of the atlas.

**Figure 2.** Nasium line drawing analysis. The UA compares the bisected skull to the APL, while the LA compares the APL to centers of vertebrae C2-C7.
**Special X-ray Equipment Alignment**

The nasium is a special view in chiropractic for several reasons. (1) It is the only view that clearly visualizes the skull condyles, atlas, and axis; (2) It is taken only after the x-ray equipment has been precisely aligned; (3) It is the only view with precise placement of the head’s median-sagittal plane inline with the central ray of the X-ray beam (utilizing head clamps and glabella alignment rod); (4) It is the only view taken with the central ray of the x-ray beam in the plane of the atlas posterior ring; and (5) It is the only view that allows for precise Geometric bisections.

Contrary to previous criticisms concerning anomalies, the nasium is the only view that anomalies of the parietal bones, atlas, and axis can be precisely identified and measured. This is due to precise positioning of the median-sagittal plane of the head with the central ray due to special equipment alignment (Figure 3).

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**Figure 3. Plumb Line Alignment**

For the nasium view and vertex views, the x-ray frame, tube, grid cabinet, and head clamps must be aligned and stay aligned when items are moved. This can be accomplished with an “Overhead Plumb Line”. A Plumb Line is affixed to the front and back walls in the x-ray room with one end passing through the center of the grid cabinet. The Plumb Line is made parallel to the “Upper Track” of the Tube Mount. This insures that the tube stays aligned with the center of grid cabinet when the tube is moved forward-backward. After checking that the grid cabinet is perpendicular to the overhead Plumb Line and tracks vertically perfectly, the Tube is positioned (with Tube Mount adjustments) underneath the Plumb Line. Reprinted with Permission from Marshall Dickholtz, DC Sr.

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A big part of the success of the nasium view in being able to visualize upper cervical subluxations is the use of head clamps and an alignment rod for precise centering of the head during x-ray exposure. The head clamps are attached to the upper back of the grid cabinet with precisely measured holes for the bolts. Since the head clamps will be moved many times for vertex views and nasium views of different sized subjects, the alignment of the head clamps must be insured for all positions. This is accomplished by using a clear plastic cube with an
imbedded metal x-y axis. Figure 4 illustrates the cube inside the head clamps and the glabella rod for centering the bisection of the eyes.

![Figure 4. Head Clamps Alignment](image)

Since the head clamps may be moved to many different positions during x-ray exams of different sized subjects, the head clamps must stay inline with the Plumb Line during all positions. This is checked using a clear plastic cube with perpendicular wires imbedded. Note that a tilting grid cabinet is considered a necessity. Reprinted with permission from Marshall Dickholtz, DC Sr.

**Reliability of Line Drawing Methodology**

The measurements (UA & LA) on the Nasium view have been subjected to several reliability studies. While a 1985 study claimed poor reliability, Barker and Jackson pointed out many methodological flaws in this 1985 study.

In a study using 38 Nasium x-rays and 3 examiners measuring each film on 2 occasions, Jackson et al. found excellent inter and intra examiner reliability; for both inter and intra-examiner reliability, Pearson’s $r > 0.92$. Standard error of measurement for the upper angle (UA) was < 0.5° (1° error using the 95% CI) and for the lower angle (LA) it was < 0.8°.

Rochester found good to excellent inter- and intra- examiner reliability; for both manual and CAD measurements of the UA and LA ranging from 0.82 – 0.99 for Design I, One way ANOVA calculations. The average standard errors for the UA was < 0.5 degrees and for the LA it was <= 0.80 degrees (1° error using the 95% CI).

Addington et al. found 80-90% agreement between examiners measurement of upper cervical subluxation on the Blair technique views.

In a study using 6 examiners marking 30 nasium x-rays, Jackson et al. found that reliability (stability over time) for the practitioners is very good. Reliability (equivalence over experts) across the practitioners is very good. The standard error of measurement for 6 examiners was 0.41° for the upper angle and 0.61° for the lower angle.

In a study of 38 sets of nasium x-rays taken before and after a sham adjustment, Jackson et al. found that all measures ≤ 1.0° indicating excellent reliability and small standard errors of measurement.
In a study using 1 nasium and 43 examiners, Seeman et al.\textsuperscript{65} found the mean difference was 0.55° for atlas laterality; 40% of the group was within 0.25 degrees and almost 75% were within 1 degree. Of importance, only 1/43 doctors found laterality on the opposite side.

Spencer\textsuperscript{64} compared the ability of experienced examiners and students to accurately measure the upper angle (atlas to skull angle) on the nasium x-ray. Atlas laterality on the nasium was found to have an inter-examiner error of 0.33°. Experienced doctors versus students did not affect the error margin.

**Reliability of Patient Positioning**

Reliability of patient positioning for the nasium view has been investigated in four separate reports.\textsuperscript{17-20} Rochester and Owens\textsuperscript{17} found that the average artifact to the atlas plane line and central skull line of 0.21 degrees but the net affect in atlas laterality is 0.0 degrees.\textsuperscript{0.21°}\textsuperscript{16} Owens and Rochester concluded “...repositioning the patient for the post radiographic exam would not introduce significant error into the x-ray analysis...”\textsuperscript{17}

In two separate investigations, Jackson et al.\textsuperscript{18,19} performed a repeatability study on the positioning for the nasium view and reported high reliability for a test-retest of patient positioning for the nasium view.\textsuperscript{18,19} For example, in 2000, Jackson et al.\textsuperscript{19} obtained initial and repeated seated nasium x-rays in 38 subjects within four hours after receiving a sham adjustment. All measures were within 1.0° between initial and repeat radiographs; no statistically significant differences were found.

Huggare\textsuperscript{20} performed an investigation analyzing natural head posture on posterior to anterior skull radiographs of 22 dental students using a repeated measures design. This view is similar to the nasium view in as much as the skull is centered and upper cervical alignment is being analyzed. Two radiographs were obtained of each subject at a one-week interval. Cranio-vertical, cranio-cervical and cervico-horizontal angles were measured. The reproducibility (method error) of the cranio-vertical, cranio-cervical and cervico-horizontal angles were 1.15°, 0.93° and 1.45°, respectively. Huggare\textsuperscript{20} concluded that the “frontal head position is more accurately reproducible than the sagittal head position”.

**Diagnostic Capabilities**

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the atlas articulation with the head can be precisely measured, the nasium provides the best visualization of C1 and C2 of all the AP views. Additionally, the nasium view is quite similar in projection and positioning to the AP Towne’s Projection medical view. The Towne’s view is taken at 35° caudal and the head is positioned without tilt or rotation. There are a multitude of boney objects visualized for normal anatomy on this view.\textsuperscript{21}

**Validity**

Investigations have found positive correlation and validity of the AP nasium radiographic alignment. Radiographic studies have found validity for the following:

1. Headaches,\textsuperscript{22}
2. ‘Gold standard’ method to measure atlas laterality.\textsuperscript{23}
Ng$^{22}$ compared the upper cervical misalignments of 10 patients with headaches to 13 asymptomatic controls. The C1 laterality (UA) on the nasium demonstrated significant differences being 3.1° in patients and 2.0° in controls.

Eriksen$^{23}$ compared the validity of radiographical assessment of atlas laterality to 6 common non-radiographic methods that are used clinically to test for atlas subluxation (leg checks, palpation, thermography, etc…). Using the Kappa statistical test, Eriksen$^{23}$ found poor correlation between upper cervical x-ray analysis and the other analyses presented indicating that radiography is the only valid assessment for atlas subluxation alignment.

**Biomechanical Validity**

For biomechanical validity, the clinician compares the spinal coupled motions on the AP nasium radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on AP nasium radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

In 1981, Harrison$^8$ reported on nasium images (Upper angles, lower angles, and CD angles) for the head postures of:

1. Head axial rotation
2. Head lateral bending
3. Lateral Head Translations.

**Outcome Investigations**

A large number of studies have been performed using the nasium x-ray view to determine and quantify upper cervical subluxations and determine treatment intervention using upper cervical techniques in a variety of patient health disorders.$^{24-62,67-75,77}$

**Level I studies:**

In total, 5 randomized clinical trials were located where the Nasium radiographic view has been used to determine adjustment interventions in upper cervical specific chiropractic techniques.$^{24-27,77}$ A review of some of these follows.

Brown et al$^{24}$ randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55%), atlas laterality was the same between the two techniques (kappa=0.08).

Statistically significant improvements were observed between SF-36 scores pre and post care. No significant differences in change from baseline scores were observed between the two techniques.

In a randomized trial, Khorshid et al$^{25}$ assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogonal upper cervical technique where radiography was used to determine the subluxation and adjustment. All subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment.

Average total ATEC improvement in the upper cervical group was 32%, while only 8.3% in the
full spine group. Two autistic children under the upper cervical adjustment protocol no longer met the criteria to be considered autistic following the interventions.

Hoiriis et al\textsuperscript{26} randomly assigned 26 chronic low back pain patients to 1 of 3 interventions: upper cervical analysis and treatment, full spine adjustments, and a combination of the two. In all groups, adjustment was determined by x-ray analysis, leg length, and palpation. Multiple outcome scales were kept and no group differences were detected; all groups improved.

In a double blind, placebo-controlled randomized trial, Bakris et al\textsuperscript{27} studied 50 subjects with Stage 1 hypertension, who received either placebo or National Upper Cervical Chiropractic (NUCCA is the Organization, Grostic is the Technique) procedures. The study duration was 8 weeks. The study group were aged 52.7 \pm 9.6 years old, and were 70\% males. The study group improved (lowered) systolic Blood Pressure (-17 \pm 9 mm Hg) versus the placebo group (-3 \pm 11 mm Hg) at p < 0.0001. In the study group, Atlas laterality was reduced on average from 1.0\(^\circ\) baseline to 0.04\(^\circ\) at week 8.

**Level II studies:** No level II studies could be found.

**Level III studies:**

In 1999, Hoiriis et al\textsuperscript{28,29} used a practice based research design to document the effects that upper cervical adjusting has on the Global Well Being Scale (GWBS) and the Rand SF-36 outcome measures scale in a patient population with predominant musculoskeletal complaints. Compared to initial measures, the 4-week outcomes showed statistically significant improvements in 6/8 of the SF-36 subscales. Whereas, compared to initial values, when the patient reached maximum chiropractic improvement statistically significant improvements in 7/8 of the SF-36 subscales were seen. They stated “Analysis of X-ray listings suggested that upper cervical chiropractic adjustment successfully reduced misalignment of the occipito-atlanto-axial complex”.\textsuperscript{28,29}

**Level IV studies:**

There are a large number of case studies, case series, and cohorts without controls in the chiropractic literature utilizing the nasium x-ray for intervention and outcomes.\textsuperscript{30-62,67-75} These investigations demonstrate that pre-post nasium x-ray alignment can be improved with chiropractic interventions and that a variety of patient disorders improve/respond to this type of intervention. Only a few will be detailed.

In 2006, Carleton et al.\textsuperscript{30} reported on a cohort of 54 retrospective patients isolated from 221 patients, who were involved in motor vehicle accidents (MVA) and who received Atlas Orthogonality Technique adjustments at a single clinic in Atlanta, Georgia. Patients had neck, shoulder, headaches, and other clinical conditions secondary to MVA. Patients received an average of 2.8 treatments sessions over 11.1 weeks, while a small subset of chronic subjects (14\%) were seen more than 10 treatments. Using the application of SCALE methods, 84\% experienced complete or near complete resolution of pain and related neck complaints, while all patients reported significant improvements in their conditions. Range of motion and x-ray improvements were measured, with atlas (C1) displacements averaging 2.8\(^\circ\) on the pre nasiums and 0.36\(^\circ\) on the post nasiums. On the NRS scale for pain, subjects reported an average pre pain scale of 7.22 and an average post pain of 2.4.

In 2006, Elster\textsuperscript{31} reported on a cohort of 60 patients, who were retrospectively selected from a single clinic, and the protocol developed by the International Upper Cervical Chiropractic
Association (IUCCA is the association, Grostic is the technique). The 60 patients were
diagnosed with the following types of chronic vertigo: benign paroxysmal positional vertigo
(BPPV), cervicogenic, disembarkment syndrome, labyrinthitis, Meniere’s, and migraine-
associated vertigo (MAV). Of the 60 vertigo patients, 56 recalled experiencing at least one head
or neck trauma prior to the onset of vertigo including auto accidents (25 patients); sporting
accidents, such as skiing, cycling, or horseback riding (sixteen patients); or falls on icy sidewalks
or down stairs (six patients). Two diagnostic tests, paraspinal digital infrared imaging and laser-
aligned radiography, were performed. Upper cervical subluxations were found in all 60 cases.
All 60 patients responded to IUCCA upper cervical care within one to six months of treatment.
Forty-eight patients were symptom-free following treatment and twelve cases were improved in
that the severity and/or frequency of vertigo episodes were reduced.

Aldis and Hill\textsuperscript{32} reviewed 140 cases treated with the Pettibon upper cervical methods.
Atlas laterality (UA) and lower angle (LA) on the Nasium and axial rotation on the vertex were
compared pre and post-adjustment. Statistically significant differences were noted with an
average reduction of the three subluxation measures on the post radiographs.

Grostic and DeBoer\textsuperscript{33} retrospectively examined 523 cases treated and analyzed with the
Grostic technique. Pre and post UA and axial rotation subluxations on the Nasium and Vertex
views were used as outcome measures. Initial radiographic measures were UA = 2.63° and atlas
rotation = 2.75°. On the post-treatment radiographs an approximate reduction of 1.23° in the UA
and 1.32° for the axial rotation subluxations was found.

Anderson\textsuperscript{34} retrospectively reported on the pre and post upper cervical alignment of 301
patients treated with the Grostic technique. The pre-post nasium view showed a consistent
average reduction of atlas laterality.

Peet, Garde, and Marko\textsuperscript{67-75} have presented several case reports where the Chiropractic
Biophysics technique (CBP\textsuperscript{®}) Nasium analysis and adjustments were used in the treatment of
pediatric patients with a variety of health related conditions. These reports demonstrate
consistent reduction of upper cervical subluxations using the Nasium and x-ray and consequent
improvement in health status of pediatric patients.

\textbf{Special Filtration}

Although medical/chiropractic x-ray exposure is only a fraction of the yearly background
radiation to which all animals are exposed (see Section VII on Radiation Safety), in 2007,
Eriksen\textsuperscript{76} reported on Lead foil compensating filters that reduce the exposure on cervical
radiographic views (lateral, nasium, and vertex) by 65%, with a reduction of 97% to the majority
of the skull and part of the eyes, on the nasium and 78% on the vertex.
References

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APOM Radiographic View

RECOMMENDATION

The APOM Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Population Studies Class 4, Reliability Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D.

Introduction

According to Hart a medical doctor in Germany appears to have been the first to describe the procedure for obtaining the anterior to posterior open mouth (APOM) radiographic view. By the 1930s, chiropractors were including the occiput in the view's analysis, along with the traditional C1 and C2 assessment.

The AP Open Mouth (APOM) cervical radiographic view is an integral part of the Davis Series; a set of 7 radiographs of the neck recommended after a whiplash injury. Figure 1.

Figure 1. The APOM upper cervical view. For the APOM view, the patient stands or sits with head against the grid cabinet and mouth open. The tube is horizontal to the uvula and collimation is below the eyes.
This view requires no special equipment and positioning, with the exception of asking the subject to open his/her mouth. In a section on a routine spine evaluation, Hildebrandt\textsuperscript{2} did not discuss this APOM view.

Johnson and Lucas\textsuperscript{3} have reviewed 1033 nontraumatic cases and found only a small percentage had abnormalities visible on the APOM. They agreed with the APOM’s use in trauma cases, but suggested that the APOM be only sparingly used in nontraumatic cases. The non-trauma cases where the APOM is recommended by them are:

1. congenital anomalies
2. history of previous trauma
3. osteoarthritis
4. rheumatoid arthritis
5. Down syndrome
6. ankylosing spondylitis.

**Reliability of Line Drawing Methodology**

Only one investigation detailing the reliability of line drawing measures of subluxation on the APOM could be found. In a 1996 case report,\textsuperscript{10} three examiners analyzed three separate anterior-posterior open mouth radiographs taken in 1985, 1986, and 1989 of the same patient. Measurements included laterality of the atlas and axis, side of acute atlas angle, and extent of vertebral rotation. No significant examiner differences were reported.\textsuperscript{10}

Although only 1 small investigation could be located on measurement reliability of the APOM, it is the consensus of the PCCRP panel that measurements on this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) x-ray line drawing is simply Euclidian Geometry and 2) that all other line drawing methods for spinal subluxation measurement have been found to be reliable (See Section VIII).

**Reliability of Patient Positioning**

Although no investigations could be located on positioning reliability of the APOM, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable\textsuperscript{15} and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

There is, however, an optimal positioning procedure to improve visualization of the upper cervical spine on the APOM radiographic view. Wylie\textsuperscript{9} investigated two different patient positions for obtaining the APOM radiograph; where 30 subjects were x-rayed for each view. The 1\textsuperscript{st} method was the standard approach where the upper incisors and the mastoid process are placed in a horizontal position relative to the reference floor level. The 2\textsuperscript{nd} method utilized a slight head extension with the central ray bisecting the atlas (just inferior to the mastoid process); equal distance between the upper and lower teeth relative to the central ray is needed. The 2\textsuperscript{nd} method was found to provide clinically superior visualization of upper cervical structures.\textsuperscript{9}

**Diagnostic Capabilities**

Diagnostic usability is inherent on each radiographic view for the object on the central ray. In the case for the APOM view, the objects on the central ray are the two upper cervical vertebrae, C1 and C2. This view, as an integral part of a Davis Series in whiplash, is used to
determine the possible dislocations, possible fractures, and soft tissue injuries to the C1 and C2 area. However, besides just the Davis Series, the lateral cervical, AP cervical view, and the APOM have been recommended in all cases of cervical spine trauma.\textsuperscript{1,5,6} Some have suggested that the APOM view should be included in all cervical spine radiographic series regardless of indication of trauma or pain.\textsuperscript{4,5} Furthermore, some chiropractic clinicians and techniques include the biomechanical assessment of the atlanto-occipital and atlanto-axial articulations by using the AP open-mouth radiograph procedure as part of their treatment decision making process.\textsuperscript{8,12}

**Validity**

Besides the multitude of fractures, dislocations, and soft tissue injuries reported in the literature for the APOM view during a Davis series, Johnson and Lucas reported on 10 non-trauma cases, with rheumatoid arthritis, metastatic carcinoma, degenerative joint disease, Down syndrome, erosion of the odontoid, and atlanto-axis instability.\textsuperscript{3} Sickesz and VanDerSchaar\textsuperscript{12} described their experience dealing with several thousand whiplash cases over 3 decades by reporting the “typical presentation” of subluxation displacements of the upper cervical spine, C0-C3, on the APOM radiograph. They described y-axis and z-axis (gravitational axis and lateral flexion) displacements as being very common after whiplash.

An investigation by Yi-Kai et al\textsuperscript{11} questioned the validity of APOM for upper cervical subluxation measurements.\textsuperscript{11} Yi-Kai et al\textsuperscript{11} concluded that APOM upper cervical alignments are not different for 87 neck pain patients compared to 21 controls. The only measurement recorded was the Odontoid to lateral mass interspace distance on the left versus right side; no angular measures were recorded nor was the ‘overhang’ of C1-C2 joint on the outside (these measures are more clinically and biomechanically relevant). Problematically, Yi-Kai et al\textsuperscript{11} lumped acute (1 day duration) and chronic (4 years duration) subjects together and subjects were a ‘conglomeration’ of conditions ranging from neck pain and headaches to shoulder pain and vertigo. Therefore, the study by Yi-Kai et al\textsuperscript{11} has serious methodological flaws.

**Biomechanical Validity:**

For biomechanical validity, the clinician compares the spinal coupled motions on the APOM radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on APOM cervical radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent APOM radiographic patterns.\textsuperscript{13,14}

**Outcome Investigations**

Only two investigations reporting on the pre and post subluxation alignment of the upper cervical spine on the APOM radiographic view could be located.\textsuperscript{10,12} However, several upper cervical techniques utilize this radiographic view in their initial decision making process although post-treatment APOM radiographs may not be obtained.\textsuperscript{16}

**Level I Studies:** No Level I studies could be located.
Level II Studies: No Level II studies could be located.

Level III Studies: No Level III studies could be located.

***Level IV Studies:***

In a case report with a 4 year follow up, Hart\textsuperscript{10} reported non-statistically but clinically significant improvements in the upper cervical alignment of initial and follow-up APOM radiographs. Hart\textsuperscript{10} noted that the patient’s condition improved although the ‘overall pattern’ of the patient’s subluxation on x-ray remained the same.

In a retrospective case series, Sickesz and VanDerSchaar\textsuperscript{12} reported on 40 randomly selected patients with chronic whiplash associated disorders. The APOM subluxation displacements of C1 and C2 were utilized to help determine intervention. Compared to initial presentation, the 3-month follow-up examination showed complete resolution in the majority of subjects’ complaints.


4. Blair Protracto Views

RECOMMENDATION

The Blair Protracto Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, IV and V, Biomechanics, Reliability Studies Class 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The Blair Condyle Radiographic views were originated by Blair.1-5 The term Condyle Protracto view was used by Blair. He originated the idea that the head may translate-subluxate obliquely on the atlas along the long axis of one lateral mass. If this occurred, the opposite side skull condyle-lateral mass articulation will have a laterolisthesis type displacement. A Base Posterior radiographic view is needed before the Blair “Convergence Angles” can be determined. (Figure 1)

This condyle view requires a little more work in equipment and positioning time compared to any other AP cervical view. Blair devised a special head clamp system in which the head clamps could be rotated away from the grid cabinet. He did this in the amount exactly equal to each Convergence angle. In actuality, the head was rotated by the amount of the Convergence angle, and thus, was in a slight oblique position relative to a true AP cervical or nasium. The central ray was therefore directed through the maxillary sinus opposite the condyle-lateral mass articulation to be studied. (Figure 2).

Figure 1. The Blair Condyle Convergence Angles were measured on a Base Posterior radiographic view. These angles determined the amount of head rotation for taking the Blair Condyle Radiographic views, which are in effect slight obliques.
While the 2006 Hubbard text suggests that 8 views are required in the Blair technique, the Blair Society of Lubbock, Texas disagrees with the use of stereo views. The eight radiographic views suggested by Hubbard are:

1. Base Posterior
2. A-P Open Mouth
3. A-P Cervical
4. Lateral Cervical
5. Left lateral Stereo (2 exposures shift slightly from each other)
6. Right Lateral Stereo (2 exposures shift slightly from each other)
7. Left Blair Protracto View (or so called Oblique nasium)
8. Right Blair Protracto View (or so called Oblique nasium)

To draw the “Convergence angles” on the Base Posterior view, the medial junction of the anterior arch of C1 and the medial junction of the posterior arch of C1 with each lateral mass are determined. Two perpendiculars are drawn to the edge of the lateral masses from a line connecting these medial lateral mass points. These lines are bisected and a line is drawn through these bisected points out through the area of the orbits.

Figure 4 illustrates a patient set up for a “oblique nasium” or Blair Protracto view, with Blair head clamps that can rotate to the convergence angle determined from the Base posterior View. To bisect the skull, Hubbard uses a perpendicular bisector of a line through the two ear markers (Figure 4).
Figure 3. Blair Constructions on the Base Posterior View. The actual construction of the Blair “Convergence Angles” is illustrated. Lines are drawn along the medial edge of each lateral mass by locating the junction points of each lateral mass with the anterior arch and posterior arch of C1. Perpendicular to these lines at these points, two lines on each condyle are drawn across the lateral mass-condyle area. Each line is bisected. A line through the bisected lines on each condyle is drawn forward through the orbit area. Photographs courtesy of Dr. Todd Hubbard.

Figure 4. Blair Protracto Condyle View. After measuring the convergence angle on each condyle on the Base Posterior View, the patient is x-rayed along these two projection lines on an “Oblique Nasium” or Blair Protracto View. The patient sits in a movable chair and the rotatable Blair head clamps are turned to the measured angle. The patient is then tuned to this angle and the head clamps positioned. The central ray is along the atlas plane line determined from the lateral. Photographs courtesy of Dr. Todd Hubbard.
The structure of the articulation, that Blair considered to be of interest, is where the most lateral superior articulating surface of the lateral mass meets the most lateral inferior articulating surface of the condyle. When viewed at this angle (along the longitudinal axis of the condyle) the most lateral part of the condyle–lateral mass should line up without any underlapping or overlapping (Figure 5).

Figure 5A-C. Analysis on the Blair Protracto View. On the “Oblique Nasium” = Blair Protracto View, the most lateral superior articulating surface of the lateral mass where it meets the most lateral inferior articulating surface of the condyle is the focus of analysis. Because the projection is through the maxillary sinus and part of the orbit, the beginning practitioner has difficulty discerning bony structures on this projection along the long axis of one condyle. Photographs courtesy of Dr. Todd Hubbard.
While other Chiropractic Techniques, such as BJ Palmer’s HIO, use measurements on the Base Posterior view to determine the care of a patient, no one made the measurements that Blair made. The Condyle Protracto Views are specific to Blair Technique. Without this view, the Blair Practitioner cannot determine the proper care of his/her patient. Information from these views is used to position the patient for adjusting, to determine where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted.

**Reliability**

Addington et al\(^7,8\) found 80-90% agreement for the direction of subluxation between examiners for upper cervical subluxation on the Blair technique views.

**Reliability of Patient Positioning**

Although no investigations could be located on positioning reliability of the Blair Protracto views, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable\(^9\) and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

**Diagnostic Capabilities**

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the condyle-atlas articulation on each side of the head can be precisely visualized, these views provides the best visualization of maxillary sinuses.

**Validity**

**Biomechanical Validity:**

For biomechanical validity, the clinician compares the spinal coupled motions on the Blair Protracto radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on the Blair radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present. Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement patterns.\(^10,12\)

**Outcome Investigations**

**Level I Studies:**

Brown et al\(^11\) randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55%), atlas laterality was the same between the two techniques (kappa=0.08). Statistically significant improvements were observed between SF-36 scores pre and post care. No significant differences in change from baseline scores were observed between the two techniques.
Level II Studies: No Level II Studies could be located.

Level III Studies: No Level III Studies could be located.

Level IV Studies:

There are several case studies, case series, and cohorts without controls in the chiropractic literature utilizing the Blair Protracto x-ray views for intervention and outcomes.\textsuperscript{13-17} These investigations clearly show that occipital-atlas alignment on the Blair x-ray views can be improved, can alter chiropractic intervention techniques, and that a variety of patient disorders improve/respond to this type of analysis and intervention.

Recent Text

In 2006, a new text, with Blair Technique included, was written by Hubbard\textsuperscript{17} and published by Palmer Chiropractic College in Davenport, Iowa. This text suggested Lateral Stereo views (with tube shifted left & right), which are not necessarily promoted by the Blair Society in Lubbock, Texas.
References

1. Blair WG. For Evaluation; For Progress, Part I; International Review of Chiropractic 22(8):8-11 (Feb. 1968)
2. Blair WG. For Evaluation; For Progress, Part II; International Review of Chiropractic 22(9):10-14 (March. 1968)
5. Addington EA. Blair Research Society in Lubbock, Texas.
5. Vertex View

RECOMMENDATION

The Vertex Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, III, IV, V, Biomechanics, Reliability Studies Class 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The Vertex upper cervical radiographic view was originated by A.A. Wernsing, DC\textsuperscript{1} in 1930 and later adapted in the Grostic Technique.\textsuperscript{2} Although Wernsing obtained this view without the use of head clamps, Grostic recommended their use. This view is taken sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (Figure 1).

This view requires some special equipment and positioning. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40 inches, and precision head clamps.

The patient is positioned facing the grid cabinet, which is placed on angle. (See Figure 1)

Using the orientation of the APL in space, the tube is positioned perpendicular to this line. An
imaginary line, formed from the glabella to the base of the occiput, is visualized and then the central ray is positioned so that it is perpendicular to this line. The central skull being formed by connecting the center point of the floor of the ethmoid bone with the center of the neural canal at the atlanto-axial articulation. The central ray should strike the approximate center of the film.

Measurements are made on the Vertex view in degrees (Figure 2). The skull is bisected using the edges of the parietal bones or by a line following the mid-floor structures of the cranium. Depending on the Technique system, a line is drawn through the atlas (APL in Vertex view). Wernsing and Grostic utilized the foramina (intertransversariae) for the vertebral arteries within the transverse processes of C1. These two lines create an Angle of rotation of the head relative to C1 about vertical gravity.

Many Upper Cervical Chiropractic Techniques use measurements on the Vertex view to determine the care of a patient. This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore, these techniques require that a post treatment Vertex x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

**Reliability of Line Drawing Methodology**

In a 1992 review of the literature on upper cervical x-ray marking studies, Owens concluded that studies have reported inter- and intra-examiner reliability are sufficient to measure rotational displacements of C1 to within ± 1° on the Vertex x-ray view. In 1994 Rochester had four blinded examiners measure/re-measure atlas rotation relative to the skull on 10 vertex x-rays using both manual and CAD methods. The average intra-examiners standard errors ranged from 0.24 to 0.70 degrees with the inter-examiner average standard error at 0.68 degrees. The reliability was fair.

**Reliability of Patient Positioning**

Although no investigations could be located on positioning reliability of the Vertex view, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be

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**Figure 2.** The Vertex view is obtained by placing the tube overhead perpendicular to the atlas plane line (APL) determined in the lateral view (Figure 1). Measurements on this view are to determine any axial rotation of the skull-atlas joint. The skull is bisected (Center skull line) and the APL is drawn through the vertebral artery holes in the C1 transverse processes. In this example, the atlas is rotated anterior on the left side.
repeatable\textsuperscript{15} and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

\textbf{Diagnostic Capabilities}

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the atlas articulation with the head in axial rotation can be precisely measured, the Vertex view provides the best visualization of C1 for Jefferson fractures. Additionally, the Vertex view is quite similar in projection and positioning to the Water’s Projection medical view. For the Water’s view, the patient faces the grid cabinet, extends his/her head with no rotation or tilt and the view is taken at 37° caudal. There are a multitude of boney objects visualized for normal anatomy on this view.\textsuperscript{16}

\textbf{Validity}

The vertex view was an integral part of several upper cervical techniques including Wernsing’s Atlas Specific, Grostic, NUCCA, Sweat’s Atlas Orthogonal, Pettibon, Don Jones’ Life Cervical, Orthospinology, and Harrison’s CBP Technique. There are numerous case studies from these techniques, but also this radiographic view is featured in a recent text by Erikson.\textsuperscript{3} Since the Base Posterior view and the Vertex view are taken along the same projection line through the head and have similar measurements for atlas rotation compared to the skull,\textsuperscript{17} validity or efficacy of one view is analogous for the other view.

\textbf{Biomechanical Validity:}

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Vertex radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on the Vertex radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement pattern and magnitude for the rotation of the skull and atlas about gravity.\textsuperscript{18-21}

\textbf{Outcome Investigations}

The C1 rotation under the skull has been used at the Institute for Orthomanual Therapy in The Hague, The Netherlands and at the International Biomedical Center in Leende, The Netherlands.\textsuperscript{22} Several outcome investigations have been reported where the Vertex view was an integral part of the treatment decision making process. These investigations clearly show that occipital-atlas alignment on the Vertex x-ray view can be improved, can alter chiropractic intervention techniques, and that a variety of patient disorders improve/respond to this type of analysis and intervention.\textsuperscript{7,22-41}

\textbf{Level I Studies:}

At least 3 randomized trials were found where the Vertex radiographic view was utilized to direct treatment interventions.\textsuperscript{23-24,41} Only the most recent of these will be discussed.

In a randomized trial, Khorshid et al\textsuperscript{23} assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogonal upper cervical technique where the Vertex radiograph was one of the x-ray views used to determine the subluxation and adjustment. All
subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment. Average total ATEC improvement in the upper cervical group was 32%, while only 8.3% in the full spine group. Two autistic children under the upper cervical adjustment protocol no longer met the criteria to be considered autistic following the interventions. Post adjustment Vertex x-rays showed reduction of the structural subluxation of the skull relative to the atlas.

**Level II Studies:** No Level II studies could be located.

**Level III Studies:**

In 1999, Hoiriis et al²⁵ used a practice based research design to document the effects that upper cervical adjusting has on the Global Well Being Scale (GWBS) and the Rand SF-36 outcome measures scale in a patient population with predominant musculoskeletal complaints. Compared to initial measures, the 4-week outcomes showed statistically significant improvements in 6/8 of the SF-36 subscales. Whereas, compared to initial values, when the patient reached maximum chiropractic improvement statistically significant improvements in 7/8 of the SF-36 subscales were seen.

**Level IV Studies:**

There are a large number of case studies, case series, and cohorts without controls in the chiropractic literature utilizing the Vertex radiographic view for intervention and outcomes.⁷,²²,²⁶-⁴⁰ These investigations clearly show that pre-post Vertex x-ray alignment can be improved with chiropractic interventions and that a variety of patient disorders improve/respond to this type of analysis and intervention. Only a few will be detailed.

Grostic and DeBoer⁷ retrospectively examined 523 cases treated and analyzed with the Grostic technique. Pre and post UA (upper angle) and axial rotation subluxations on the Nasium and Vertex views were used as outcome measures. Initial radiographic measures were UA = 2.63° and atlas rotation = 2.75°. On the post-treatment radiographs an approximate reduction of 1.23° in the UA and 1.32° for the axial rotation subluxations was found.

In 2004, Sickesz and VanDerSchaar²² reported on their experiences with several thousand cases of whiplash injury, where the Vertex radiographic measurement has been used to determine C1 rotation under the skull. They demonstrate adjustments to correct this “luxation” of C1 and report on 40 retrospective randomly selected cases.

Aldis and Hill²⁶ reviewed 140 cases treated with the Pettibon upper cervical methods. Atlas laterality (UA) and lower angle (LA) on the Nasium and axial rotation on the vertex were compared pre and post-adjustment. Statistically significant differences were noted with an average reduction of the three subluxation measures on the post radiographs.

Anderson²⁷ retrospectively reported on the pre and post upper cervical alignment of 301 patients treated with the Grostic technique. The Vertex view identified that most patients attained a 2° average reduction in axial rotation while 15% of the subjects attained a 4° or more reduction in subluxation displacement.


25. Hoiriis KT, Owens EF, Pfleger B. Changes in General Health Status During Upper Cervical Chiropractic Care: A Practice Based Research Project CRJ Volume 4, Number 1 Spring 1997.


6. Base Posterior Radiographic View

**RECOMMENDATION**

The Base Posterior Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

**Supporting Evidence:** Clinical Levels I, IV, V, Biomechanics, and Validity.

**PCCRP Evidence Grade:** Clinical Studies = B, C, D.

**Introduction**

The Base Posterior upper cervical radiographic view was used in HIO since the early 1900’s.\(^1\) This view is also an integral part of the Blair Technique.\(^2\) This view is taken sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (Figure 1) The Vertex view and Base Posterior view have similar goals and measurements.

*Figure 1. The Base Posterior upper cervical view. For the Base Posterior view, the patient sits on a movable positioning chair. The grid cabinet is positioned overhead and the tube is positioned between the knees. The head is positioned to take out rotation & tilt.*
This view requires some special equipment and positioning. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40 inches. The tube and tube stand must be movable enough to allow the tube to be positioned between the patient’s knees.

A lateral cervical x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject’s facial features. This tilt and tube height is derived from the atlas plane line on the lateral cervical view. On the lateral view, a line through the atlas is compared to horizontal and given either an “S-Line” designation. The “S-Line” is denoted S –5 to S5 depending on where the atlas sagittal line intersects the anterior skull structures. The patient is positioned sitting with the grid cabinet overhead, which is placed on an angle. (see Figure 1) Using the orientation of the APL in space, the tube is positioned perpendicular to this line.

Measurements are made on the Base Posterior view in degrees (see Figure 2). The skull is bisected using the edges of the parietal bones or by a line following the mid-floor structures of the cranium. Depending on the Technique system, a line is drawn through the atlas (APL in Base Posterior view). The mid-foramen for the vertebral arteries is often used as the two points to create an atlas plane line (APL). These two lines (bisected skull floor structures and APL) create an Angle of rotation of the head relative to C1 about vertical gravity.

Many Upper Cervical Chiropractic Techniques use measurements on the Base Posterior view to determine the care of a patient. This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore, these techniques require that a post treatment Base Posterior x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

**Reliability of Line Drawing Methodology**

To our knowledge the Base Posterior view has never been subjected to a reliability study. However, it is the consensus of the PCCRP panel that measurements on the Base Posterior radiographic view would be reliable. This PCCRP consensus opinion is due to the facts that:

- The Base Posterior view is obtained on the same angle as the Vertex view except the tube and grid cabinet are reversed. (Figure 1). The major difference between the two views is that the atlas will appear larger (magnified) in the Base Posterior view.
- Measurements on this view are to determine any axial rotation of the skull-atlas joint. The skull is bisected (Center skull line) and the APL is drawn through the vertebral artery holes in the C1 transverse processes. In this example, C1 is rotated anterior on the left.
Rochester\textsuperscript{3} studied the reliability of four blinded examiners measuring and re-measuring atlas rotation relative to the skull on 10 vertex x-rays using both manual and CAD methods. The average intra-examiners standard errors ranged from 0.24 to 0.70 degrees with the inter-examiner average standard error at 0.68 degrees. The reliability was fair. The Vertex and Base posterior views are similar and are simply taken from differing projections. 2) X-ray line drawing is simply Euclidian Geometry and 3) that all other line drawing methods for spinal subluxation measurement have been found to be reliable (See Section VIII).

**Reliability of Patient Positioning**

No investigations could be located on positioning reliability of the Base Posterior radiographic view. However, it is the consensus of the PCCRP panel that patient positioning for the Base Posterior radiographic view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) posture has been shown to be repeatable\textsuperscript{4} and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for similar radiographic views.

**Diagnostic Capabilities**

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being one of the only views on which the atlas articulation with the head in axial rotation can be precisely measured, the Base Posterior view, like the Vertex view, provides the best visualization of C1 for Jefferson fractures. Additionally, the Base Posterior view and the Vertex view are quite similar in projection and positioning to the Water’s Projection medical view. For the Water’s view, the patient faces the grid cabinet, extends his/her head with no rotation or tilt and the view is taken at 37\textdegree caudal. There are a multitude of boney objects visualized for normal anatomy on this view.\textsuperscript{5}

**Validity**

**Biomechanical Validity:**

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Base Posterior radiograph to the published results of “main motion coupled motion” performed on head postural movements. If the usual coupled motion patterns on the Base Posterior radiograph are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present. Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement pattern and magnitude for the rotation of the skull and atlas about gravity.\textsuperscript{6-9}

**Outcome Investigations**

**Level I Studies:**

Brown et al\textsuperscript{10} randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Radiographic examination including the Base Posterior radiographic view, was performed on each subject. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55\%), atlas laterality was the same between the two techniques (kappa=0.08). Statistically significant improvements were observed between SF-36 scores pre
and post care. No significant differences in change from baseline scores were observed between the two techniques.

**Level II Studies:** No Level II studies could be located.

**Level III Studies:** No Level III studies could be located.

**Level IV Studies:**

The Base Posterior view was an integral part of HIO technique originated and used by BJ Palmer. There are numerous case studies in Palmer’s texts that can be obtained from the Palmer Chiropractic College Library.1

In 2004, Sickesz and VanDerSchaar11 reported on their experiences with several thousand cases of whiplash injury, where this x-ray view has been use to determine C1 rotation under the skull. Interestingly, they give credit to Palmer for originating the “Palmer basal-posterior projection”. They demonstrate adjustments to correct this “luxation” of C1 and report on a sample of 40 retrospective, randomly selected cases.

**References**

1. Palmer BJ. The Subluxation Specific, the Adjustment Specific. Davenport, IA: Palmer College of Chiropractic, 1934.
7. Lateral Cervical Radiographic View

RECOMMENDATION

The Lateral Cervical Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.


PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

In radiography of the cervical spine, the first view to be obtained is generally the lateral cervical view. Care should be taken to insure that several structures are visible from the sellae turcica superiorly, the hard palate anteriorly, the posterior occiput, to the lower cervical spine including T1 inferiorly. In many cases, a lateral cervical thoracic filter is needed in order to adequately visualize the lower cervical spine.

The lateral cervical is taken at the standard tube distance of 182.9 cm (72 inches) with the central ray located approximately at the C4 level, however, upper cervical doctors often align the central ray with the upper cervical spine.11 For lateral cervical x-rays, the patient’s shoulders are positioned perpendicular to the x-ray bucky. There are several methods of patient positioning procedures where some authors recommend placing the patient in an ‘idealized’ neutral position with the hard palate level; while others recommend the ‘self balance position’.1-15 Regardless of methodology, as discussed below, the positioning is repeatable.

Since chiropractic clinicians are interested in the alignment of the patient’s spine, the self balance position may be more appropriate to ascertain the patient’s unique subluxation alignment. For this self balance position, the patient is instructed to close his/her eyes, to flex and extend his/her head twice, and come to a resting neutral position. This neutral resting posture is where the patient perceives his/her head to be looking straight, forward. The eyes are then opened and the patient is instructed to look straight ahead without moving. The patient’s abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the ‘self balance positioning’ of a patient with slight head flexion in their neutral resting posture.

Reliability of Measurement Methods

Numerous researchers have published reliability studies on lateral cervical radiographic measurements.11,19-27 Harrison et al19,20 investigated reliability of the Harrison Posterior Tangent and Cobb methods for measurement of the lateral cervical radiographic alignment. (See Figure 2 and 3). They19,20 reported that these lines have high reliability (0.70 < ICC, 0.70 < Pearson r ). This method of line drawing has a very low standard error of measurement (SEM < 2.0 degrees) and small mean absolute values of observers’ differences (1.0 < SEM ≤ 3.0 degrees).20
**Figure 1.** Self balance position. The patient is instructed to close his/her eyes, to flex and extend his/her head twice, and come to a resting neutral position. The eyes are then opened and the patient is instructed to look straight ahead without moving. The patient’s abnormal sagittal plane posture is left as is. The example of head flexion is shown.

**Figure 2.** Harrison Posterior Tangent Method. In A, the total curve from C2-C7 for measuring the absolute rotation angle (ARA). In B, relative rotation angles (RRA’s) are shown to quantify segmental angles of cervical spine curvature. In C, vertical alignment of sagittal balance is shown.
Other investigators have found the 4-line Cobb angle to be reliable with a standard error of measurement (SEM) between 4°-9°. Segmental Cobb angles have been utilized for analysis of juxta-positioned segments and these segmental Cobb or endplate angles have been found to be reliable. Hermann and Geisler found high intra- and inter-class correlations (ICC’s) and low measurement errors (1.8° and 0.7mm) for a new computerized measurement of cervical segmental lordosis.

Shoda et al investigated the reliability of several upper cervical measurement methods. They found intra-observer errors for Chamberlain’s line, McRae’s line, and McGregor’s line were 2.0°, 4.7°, and 1.5° respectively while intra-observer ICCs were 0.956, 0.835, 0.975. Inter-observer mean errors for these lines were 2.3°, 5.0°, and 1.4° respectively; while inter-observer ICC’s were 0.939, 0.802, and 0.972.

In 1994, Rochester reported on four blinded examiners who measured and re-measured 10 lateral cervical films for the “S-Line” used in upper cervical techniques. Two examiners used manual marking methods and two examiners used CAD. The inter-examiner reliability was fair (0.39 R manual and 0.52 R CAD) and the intra-examiner reliability for the S-Line measurement was fair to excellent (0.86 R – 0.87 R for manual analysis and 0.68 R – 0.95 R for CAD analysis) with small standard errors.

Collectively these studies indicate that measurement of the lateral cervical radiographic alignment has excellent observer reliability for a variety of methodology.
Repeatability of Patient Positioning

At least 15 manuscripts have been published describing the repeatability of lateral cervical and lateral skull radiographs.\textsuperscript{1-15} For example, Hellsing et al.\textsuperscript{1} performed a reproducibility study of cephalometric radiographs of 14 adults over a period of 8 months. Two exposures were taken in each series of each patient. The first was without the use of stabilizing ear rods, and the second was with the ear rods. A digitizer was used to measure 13 angles and 12 lines relative to horizontal/vertical. After an average period of 8 months, no significant differences on follow-up films were found.

Foster et al.\textsuperscript{2} performed a repeatability study of 9 subjects with follow-up radiographs performed after an interval of at least 2 weeks. The mean error for the angles measured ranged from 3.0° to 4.8°. However, the digitizing measurements revealed a method error ranging from 0.86° to 4.9°, indicating that the x-ray positioning errors were within the mean errors of the measurement method.

In a retrospective analysis, Luyk et al.\textsuperscript{3} assessed the reproducibility of the natural head posture (NHP) with a mean of 4.3 radiographs per patient. Eighteen patients were analyzed in the NHP in a series of films taken over an average of a 3-year period. A control group comprised of 18 patients (where a cephalostat with ear rods for radiography in orthodontic planning was utilized) had at least 3 cephalostat films taken over a period of 3 years. The reproducibility varied by a mean of only 5.2° for the angle measured. Their results showed no significant differences (p > 0.7) between the two groups or the examiners. Similarly, Houston et al.\textsuperscript{4} obtained initial and repeat cephalostat radiographs of 24 patients on the same day. X-ray positioning errors were found to be small and below the standard error of the measurement system.

Cook et al.\textsuperscript{5,6} and Peng and Cook\textsuperscript{7} performed a series of NHP repeatability radiographs with short and longitudinal follow up. In the first of their series\textsuperscript{5}, 217 children were randomly allocated to six different radiographic positioning groups. Repeat radiographs were taken at different intervals between the groups: immediate (4-10 minutes) repeat radiographs, delayed (1-2 hours) repeat radiographs, and months (3-6 months) later. In one of their groups, where a self balance position with a mirror was used on the initial and the NHP without a mirror on the repeat, significant differences were detected at p ≤ 0.01; the maximum error was only 2.9°. In 5 of the 6 groups, no significant differences were found between the initial and repeat radiographs. In both a 5\textsuperscript{6} and 15\textsuperscript{7} year follow up on these subjects, similar repositioning errors were found on the repeated radiographs. Peng and Cook\textsuperscript{7} stated, “The 15 year head posture reproducibility therefore compared well to the original repeat recordings after 5-10 minutes and the later repeats after 5 years.”

Siersbaek-Nielsen and Solow\textsuperscript{8} took initial and repeat lateral cephalometric films of 30 subjects between the ages of 6-15 years. The x-rays were taken between 1-35 days apart; where 21 were made by the same examiner and nine were taken by different examiners for the initial and repeat x-rays. All measured values showed differences of 3.4° or less and no differences were found between examiners, age groups or time interval between x-rays. They stated, “We found no significant difference between the three different operators in spite of their different education and practical experience.”\textsuperscript{8}

Sandham\textsuperscript{9} compared repeat lateral cervical radiographs of 12 subjects with at least 1 hour between the 1\textsuperscript{st} and 2\textsuperscript{nd} x-ray. Six different measures of cervical spine and head position were calculated. No statistically significant differences were noted among any of the variables between the 1\textsuperscript{st} and repeat lateral cervical radiograph.\textsuperscript{9}
In the chiropractic literature, at least 4 studies have been performed on repeated lateral cervical radiographs of the same subject. Jackson et al.11 investigated the reliability of Pettibon patient positioning procedures. Two series of radiographs of 38 patients were taken one-half to four hours apart. Jackson et al.11 demonstrated re-positioning errors of less than 1°. Harrison and colleagues12-14 performed three separate investigations on the repeatability of lateral cervical radiographic position procedures in control group subjects with chronic neck pain. One study12 used 30 subjects with repeated x-rays taken 3-months apart, the second study13 used 24 subjects with repeat x-rays a mean of 8.1-months apart, and the third study14 used 33 subjects with repeated x-rays taken 8.5-months apart. All 3 studies found no significant changes in global or segmental angles of lateral cervical spine curvature.12-14

Lastly, in the orthopedic literature, on repeated lateral cervical radiographs of 159 subjects with an average interval of 10 years, Gore15 found no statistically significant differences in the means and standard deviations for posterior body tangent lines between C2 and C7.

Diagnostic Capabilities

If properly performed, lateral cervical spine will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies.16-18 The vertebral bodies, odontoid process, disc spaces, articular pillars, spinous processes, and the lower half of the skull boney landmarks should all be visualized. The lateral cervical view provides the chiropractic clinician with valuable information including:

1. Total cervical lordosis,
2. Segmental cervical lordosis,
3. Breaks in Georges’ line or sagittal plane translation of the posterior vertebral body and spinous lamina junction for a general stability analysis,
4. Atlas plane angle to horizontal,
5. Skull level to horizontal and upper cervical sagittal angulation,
6. General translation alignment of the skull relative to upper thorax,
7. Stages of disc, ligament & vertebral body degenerative pathologies,
8. Stage of articular process degeneration,
9. Spinal canal dimensions,
10. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been published that have found correlation and predictive validity of the lateral cervical radiographic alignment to a variety of health related conditions including:

1. acute and chronic neck pain,28-31
2. headaches,31-34
3. mental health status,120
4. whiplash associated disorders (WAD),35-46
5. segmental instability for angles 10° or greater,46,47
6. degenerative joint disease (DJD),27,48-59
7. temporal mandibular joint disorders,60
8. range of motion and segmental motion patterns,61-63
9. respiration syndromes,64-68
10. radiculopathy,69,70
11. post surgical patient outcomes,\textsuperscript{71-76} and
12. potential for soft tissue injury under impact and inertial loads.\textsuperscript{77-81}

Oppositely, a few investigations have found that the lateral cervical alignment
measurements do not correlate to and predict the findings in the above 12 categories.\textsuperscript{82-87}
However, many of these investigations have been found to be internally flawed and detailed
reviews of these studies have been performed.\textsuperscript{88-92} Still some chiropractic academics continue to
ignore these critiques\textsuperscript{88-92} and the majority of scientific evidence that supports analysis of the
sagittal cervical spine with the lateral cervical radiographic view\textsuperscript{27-81,120} in favor of Level V
evidence (opinion).\textsuperscript{93} For an example of this, in a July 2006 letter directed to the major political
organizations in Chiropractic, Whalen\textsuperscript{93} stated, “\textit{Many believe the restoration of the cervical
curve to be of utmost importance, demonstrated via X-ray. However, most, if not all studies on
this topic, fail to show that symptoms or quality of life were dependent on the curve.}” The
PCCRP panel questions if Whalen\textsuperscript{93} actually looked into the evidence before letting personal
biases dictate his position.

In contrast, it is the consensus of the PCCRP panel that the number (56 studies) and
quality of investigations finding a correlation between the lateral cervical radiographic alignment
and the conditions in the above 12 categories is superior to the few negative correlation studies.
Thus, we conclude that the lateral cervical radiographic alignment has positive correlation and
predictive validity for the above 12 categories.\textsuperscript{27-81,120}

For thorough understanding of the PCCRP panel’s position, a brief review of a few of
these studies in specific categories is provided.

\textbf{Item #1: Neck pain}

Harrison et al\textsuperscript{28} analyzed the cervical lordosis in three groups of subjects: normal subjects,
acute, and chronic neck pain subjects. Each group was limited to only lordotic cervical spines
and DJD and significant anterior head translation were excluded in all groups. Segmental and
total curve angles were calculated and circular modeling of the path of the posterior vertebral
bodies in all subjects was performed. Statistical analysis including sensitivity/specificity analysis
(ROC curves) was performed. Harrison et al\textsuperscript{28} found statistically significant differences and good
sensitivity/specificity with angle and radius of curvature measurements (acute neck pain less
than 30° and chronic neck pain less than 18°) between the groups.

In a separate evaluation of asymptomatic versus neck pain subjects, McAviney et al\textsuperscript{29}
found that a 20° lordosis (posterior tangents C2-C7) was a good cutoff value (sensitivity/specificity
using ROC curves). The association between cervical pain and lordosis ≤ 0° was highly
significant (p<0.0001). A lordosis in the range of 31° - 40° was found to have the least
percentage of symptoms and this was suggested as a clinical goal for Chiropractic treatment.

\textbf{Item #2: Headaches}

Several studies have investigated the correlation of altered cervical curve configuration to
the presence of chronic headache pain.\textsuperscript{31-34} Nagasawa et al\textsuperscript{31} compared 372 patients with tension
headaches to 225 controls matched for age and sex. They\textsuperscript{31} found statistically significant
differences between the two groups, with patients having straightened cervical curve
configurations and low set shoulders. With increasing age, the patients’ cervical curve was
straight more frequently.
In a survey of over 6,000 cases of chronic headache sufferers, Braaf and Rosner, found that “complete or segmental loss or reversal of the normal lordotic curve of the cervical spine is the most consistent characteristic feature and very often is the only abnormality found.” In 47 subjects, suffering from tension and migraine headaches, Vernon et al. found a high incidence of hypolordosis, straightened, and reversed cervical curve configurations.

Item #3: Whiplash Associated Disorders (WAD)

In two recent MRI studies by Guiliano et al., hypolordosis of the cervical spine was statistically correlated to the group with sub acute (12 weeks at least) WAD compared to a matched control group. Guiliano et al. provided detailed measurement via MRI methodology. Data from Marshall and Tuchin provides evidence that patients involved in a motor vehicle accident (MVA) injury have a 10° mean reduction in cervical lordosis compared to a control group.

Taken as a whole, the literature on patient’s involved in an MVA and those with WAD indicates that hypolordosis, straightened cervical curves, and kyphotic curves are risk factors for and are statistically correlated to several conditions including premature DJD, sub acute WAD, neck pain, neurogenic thoracic outlet syndrome, WAD categories 2 and 3, and generalized poor long-term outcomes.

Item #4: DJD

The available evidence from finite element models, analytical engineering stress/strain models, longitudinal surgical outcome studies on matched patients with and without abnormal curves and a variety of cervical spine disorders, non-surgical longitudinal studies, cross-sectional population studies, and animal models all indicate that straightened, S-curves, and kyphotic cervical curves predict and/or statistically correlate to the development and/or existence of DJD. In other words, a broad scope (not just one type of evidence) of research data points to the result that abnormal curves cause and correlate to DJD.

Outcome Investigations

Several outcome investigations have been performed using a variety of chiropractic procedures aimed at restoration of the cervical lordosis in a variety of patient pain and health disorders. In at least 2 investigations no improvement in cervical lordosis has been found following chiropractic adjustment procedures. However, 3 clinical control trials adding the chiropractic procedure of extension traction to treatment methods has shown consistent increases in cervical lordosis in treated patients versus control groups. Additionally, a small randomized trial on Autistic children comparing upper cervical technique to full spine technique has shown improved lordosis as a result of upper cervical adjustments dictated by radiography. Furthermore, many case reports, case series and cohort studies have found that several chiropractic technique procedures can improve the cervical lordosis. Collectively, these reports indicate that patients benefit by reduced pain, improved range of motion, decreased disability levels, and increased health status following chiropractic procedures that improve the cervical lordosis to near normal values. Examples of these investigations follow.
Level I Studies:
In a randomized trial, Khorshid et al.\textsuperscript{24} assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogonal upper cervical technique where radiography was used to determine the subluxation and adjustment. All subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray (Nasium, Vertex, and Lateral Cervical) and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment. Average total ATEC improvement in the upper cervical group was 32\%, while only 8.3\% in the full spine group. Two autistic children under the upper cervical adjustment protocol no longer met the criteria to be considered autistic following the interventions. Importantly, restoration of the cervical lordosis was found on post-radiography for the upper cervical treatment group. It is possible that improvement in the cervical lordosis was partly related to the better outcome of the upper cervical treatment group.

Level II Studies:
Harrison et al.\textsuperscript{13,14} presented two prospective non-randomized clinical control trials on the use of two separate cervical extension traction devices to rehabilitate the cervical lordosis in chronic neck pain patients. Extension traction was combined with traditional chiropractic treatment interventions including drop table and cervical spine manipulation. They\textsuperscript{13,14} found a 14\(^\circ\)-18\(^\circ\) increase in cervical lordosis from C2-C7 (posterior tangent lines) and simultaneous reductions in chronic neck pain intensities in the treatment group compared to no change in matched control groups who self-elected to receive no care. Long-term follow-up was performed in these two trials where rating of subjects’ pain and cervical curve improvements were found to be stable at 1.5 year follow-up.\textsuperscript{13,14}

Level III Studies:
Harrison et al.\textsuperscript{12} published a retrospective clinical control trial. Extension traction was combined with traditional chiropractic treatment interventions including drop table and diversified cervical adjusting. They\textsuperscript{12-14} found a 13.2\(^\circ\)-18\(^\circ\) increase in cervical lordosis from C2-C7 (posterior tangent lines) in the adjusting group where extension traction was added compared to no change in the control groups.

Level IV Studies:
In a case series, Wallace et al.\textsuperscript{97} found a 6\(^\circ\) improvement in cervical lordosis after 24 adjustments with the Pierce method. A posterior to anterior thrust was applied to the C5 vertebra using a drop table with the patient in the prone position.

A multitude of chiropractic case reports have found that different technique interventions can improve and/or restore an abnormal cervical spine curvature. For example, Alcantara et al.\textsuperscript{99-102} and Araghi et al.\textsuperscript{103,104} presented studies where, using Gonstead technique adjusting for the cervical spine, improved lordosis on the post treatment lateral cervical radiographs of patients with post surgical syndrome\textsuperscript{99}, seizures\textsuperscript{100}, myasthenia gravis\textsuperscript{101,103}, and bell’s palsy\textsuperscript{102}.

Kessinger and Boneva\textsuperscript{105} presented the results of a patient with acute WAD and cervical kyphosis following an MVA that changed towards lordosis following the Toggle recoil adjustment procedures.

Four separate case reports using Chiropractic Biophysics technique procedures to restore the cervical lordosis were found.\textsuperscript{106-109} Bastecki et al.\textsuperscript{106} presented the resolution of attention
deficit hyper-activity disorder with concomitant restoration of the cervical lordosis in a pediatric
case. Ferrantelli et al\textsuperscript{107} presented the resolution of chronic WAD and improvement of the
permanent impairment rating following restoration of cervical lordosis. Haas et al\textsuperscript{108} presented
the improvement in chronic pain and impairment following restoration of the cervical lordosis in
a patient suffering with syringomyelia. Colloca et al\textsuperscript{109} reported on improvements in lateral
cervical alignment along with pain and disability improvements in 3 patients with Ehlers-Danlos
Syndrome.
Coleman et al\textsuperscript{110} presented the improvements in cervical lordosis in 13 patients with
acute whiplash associated disorders (WAD) treated with activator technique methods and
stretching exercises.
Three case studies that used Pettibon technique and head weighting as the main form of
active rehabilitation, have been published by Morningstar et al\textsuperscript{111-113} All of these studies showed
significant improvement of the patient’s anterior head carriage, cervical lordosis and cervical or
thoracic pain.
In 1981, Pierce\textsuperscript{114} provided improvements in cervical lordosis in 22 cases with pre- and
post-x-ray illustrations. These improvements in lordosis were obtained with the Pierce PA drop
table adjustment at C5.
In 1991, McAlpine\textsuperscript{122} reported an average change of 7.82° of increased lordosis using
measurements taken from 10 consecutive cases, on post lateral x-rays that were taken
immediately following one Grostic (Orthospinology) hand-held instrument adjustment.
However, McAlpine indicated that patient was placed in cervical extension or the mirror image
as in CBP technique in the adjustment setup.
Lastly, physical medicine and physical therapists have shown that conservative
treatments (exercise, stretching, etc…) are able to improve a reduced cervical lordosis following
a regimen of treatments.\textsuperscript{31} The improved lateral cervical radiographic alignments are thought to
be responsible a significant amount of the pain and disability improvements.\textsuperscript{31}
References


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8. Lateral Head Weighted/Stress View

RECOMMENDATION
The Lateral Head Weighted Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV-V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D.

Introduction
The Lateral Cervical Weighted Stress View was originated by Dr. Burl Pettibon in the late 1980’s. The view is taken in the same matter as the standard Lateral Cervical View – standing or seated erect at 60-72 inches with the central ray passing through the mid-cervical spine. The only difference with this view is that the patient first has additional anterior weight secured to their forehead and usually performs some form of kinetic activity (ex.: walking on treadmill) for five minutes or more before the x-ray is taken. (Figure 1).

Figure 1 AB. In A, the patient wears the head weight symmetrically on the forehead and performs a type of kinetic activity while wearing. In B, a lateral cervical head weighting stress film is exposed to determine the effect of weighting on cervical alignment.
The head weight belt allows the user to position extra weight to their forehead. This increased head weight will induce a postural reflex (via the cervicocollic and vestibulocollic reflexes as well as the cervical mechanoreceptors) that causes a directly opposing translation of the skull on thorax to occur. A thorough literature review of the postural reflexes involved has been published by Morningstar in 2005.1

The specific indication for the chiropractic clinician obtaining this view is based on the following criteria:

1. The patient must have anterior head translation in relation to the thorax,
2. The patient must have an alteration of the normal cervical lordosis (See Section V).

The amount of weight that is applied to the patient’s forehead is determined by placing a small amount of weight (1-2 pounds) on the patient and visualizing their sagittal head on thorax posture. If their posture improves, but not completely, additional weight is applied until maximum postural correction is achieved. The patient usually then performs some type of kinetic activity for five minutes to allow the cervical spine time for neuromuscular adaptation and a Lateral Cervical Weighted Stress View is taken, with the head weight still on, to visualize the structural change that occurred as a result of the postural correction.

In some cases, the normal posture and normal cervical lordosis is restored as a result of the head weight (Figure 2). In other cases, the normal posture and lordosis is not completely restored (Figure 3). It is important for the chiropractic clinician to know if the lordosis/posture will return with the head weight as this determines if further structural rehabilitative procedures, such as corrective traction, might need to be administered.

Many Chiropractic structural corrective techniques (i.e.: Pettibon, Chiropractic Biophysics, etc.) utilize measurements from the Lateral Cervical Weighted Stress View to help determine the care of the patient and the amount of correction that is achievable through the patient’s use of head weighting.

Figure 2AB. In A, a neutral Lateral cervical x-ray is shown with anterior head translation and loss of the cervical curve. In B, a weighted lateral stress view with 4 pounds showing correction.
Reliability of Line Drawing Methodology

The measurements for segmental and total cervical lordosis and anterior head translation on the Lateral Cervical Weighted Stress View have been subjected to reliability research studies. These measurements have excellent intra and inter examiner reliability with small standard errors of measurements. In the study by Morningstar et al, analytical procedures for forward head posture radiographic measurement as outlined by Kapandji were utilized.

Reliability of Patient Positioning

Although no investigations could be located on positioning reliability of the Lateral Head Weighted/Stress view, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable and 2) that in the previous Section IX, all of the studies on the Lateral Cervical X-ray view showed reliability of positioning.

Diagnostic Capabilities

Diagnostic usability is inherent as this is the only radiographic view that allows the practitioner to visualize the amount of structural and postural correction that is attainable from the patient’s performance of corrective head weighting.

Validity

Anterior head posture and deep neck flexor muscle weakness have been associated with chronic neck pain, headaches, thoracic outlet syndrome, radicular pain, TMJ and other dental dysfunctions, and obstructive sleep apnoea. An opposite head retraction activates the deep neck flexors and has been accurately used as a measurement of neck flexor muscle endurance.

Figure 3AB. In A, a neutral lateral is shown with anterior head translation and cervical kyphosis. In B, a weighted lateral stress view with 4 pounds weight showing a lack of correction of cervical lordosis. Established, reliable measurements for cervical lordosis and anterior head translation are made on the Lateral Cervical Weighted Stress View.
A 2005 study by McLean also showed that “Corrected posture in standing required more muscle activity than habitual or forward head posture in the majority of cervicobrachial and jaw muscles, suggesting that a graduated approach to postural corrective exercises might be required in order to train the muscles to appropriately withstand the requirements of the task.”

**Biomechanical Validity:**

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Lateral Cervical Head Weighted view to the published results of “main motion coupled motion” performed on sagittal plane head postural movements. If the usual coupled motion patterns on this radiographic view are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Three studies detailing the kinematic coupling patterns of sagittal plane translation movement were found. Importantly, these studies have found the same coupling patterns. Namely, that the lower cervical vertebra (C5-C7) will flex and the cervical segments C0-C4 will extend during anterior head translation and the exact opposite pattern is present with posterior head translation.

In a 1-year follow up study on 369 subjects belonging to different occupations requiring frequent anterior displacement of the head, Choudhary reported that all the subjects had radiological loss of normal lordosis of the cervical spine (straight spine) and had tender trigger points over the trapezius and other muscles of the neck. The common postural defect in all the subjects observed was the forward-head posture. Good outcomes were achieved in this group with a rehabilitation program aimed at reduction of the anterior head posture and increasing lordosis.

Morningstar et al also published a 15 patient pilot study that used the Lateral Cervical Weighted Stress View to quantify a 0.83 inch average reduction in forward head posture and a 9.9° average increase of cervical lordosis immediately after five minutes of ambulatory head weighting on a treadmill and chiropractic adjustments.

A study by Saunders with 131 subjects, utilized the Lateral Cervical Weighted Stress View to document a 31% to 34% improvement in cervical lordosis with a reduction of forward head posture of 14-18 millimeters after five minutes of head weighting activities.

All of these studies illustrate the importance of a graduated neuromuscular rehabilitation of the normal sagittal head posture. Head weighting offers a patient friendly, easy to use, method of graduated neuromuscular postural restoration. The Lateral Cervical Weight Stress x-ray view is the only validated method to determine what effect this will have on restoration of the cervical lordosis.

**Outcome Investigations**

Two investigations reporting on the pre and post subluxation alignment of the lateral cervical view where head weighting was utilized as part of the analysis and treatment were located.

**Level I Studies:** No Level I studies could be located.

**Level II Studies:** No Level II studies could be located.

**Level III Studies:** No Level III studies could be located.
Level IV Studies:

Two case studies that used head weighting as the main form of active rehabilitation, in combination with spinal manipulation, have been published by Morningstar et al. Both of these studies showed significant improvement of the patient’s anterior head carriage, cervical lordosis and cervical or thoracic pain. The Lateral Cervical Head Weighted Stress x-ray view was an integral part of treatment determination.
References


28. Choudhary Bakhtiar S; Sapur Suneetha; Deb P S. Forward Head Posture is the Cause of 'Straight Spine Syndrome' in Many Professionals. Indian J Occupat and Environmental Med 2000 (Jul); 4 (3): 122—124.


RECOMMENDATION

The Lateral Cervical Flexion/Extension Radiographic view is indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, biomechanics and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels III-V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics and Validity Studies = a.

Introduction

The lateral flexion and extension studies represent a means to acquire more in-depth analysis of cervical spine function and pathology. These views are typically done immediately following a neutral lateral and AP views or can be done as follow up views to aid in further analysis and patient care. These two lateral cervical views are often called the “Dynamic lateral cervical flexion-extension views” when in fact they are end range of motion static views. These views are performed sitting or standing on an 8x10 or more often a 10x12 film size. (Figure 1)

Figure 1AB. The patient must be instructed to hold his/her rib cage stationary in order to eliminate thoracic cage flexion-extension. The tube is generally at 72 inches with a 10x12 film positioned at a 90 angle to the usual cassette position. Usually the head is in maximum flexion or extension for these two radiographic views. In A, the lateral cervical flexion view is illustrated. There is a 4mm antero-listhesis of C4 on C5. In B, the cervical extension view is illustrated. There is a 3.5mm retro-listhesis of C4 on C5.
Besides visualizing these two radiographs for obvious segmental instability, Ruth Jackson, MD was one of the first to draw some geometric lines for analysis. Theses “Physiological Stress Lines” were drawn as tangents to the posterior body margins of C2 and C7. Jackson thought that the location of intersection of these lines indicated the areas exposed to the greatest stress. In her classic 1957 and 1978 texts, she indicated that her “Physiological Stress Lines” should intersect at C6 in flexion and C4-C5 discs space in extension. Shortly thereafter in 1960, Zatzkin and Kveton measured the angle of intersection in Jackson stress lines to determine a normal cervical curve and compared this in whiplash cases.

One of the first biomechanical studies designed to determine what ligaments are involved in segmental instability was performed by White et al in 1975. Using cadaver spines, they sectioned ligaments while loading the spines in flexion or extension. With all ligaments intact, they determined values of a maximum 2.7 mm in segmental translation (x-ray magnification can make this appear as 3.5 mm) and 10.7° in angular displacement. Any translation of 4.9 mm or higher is near total failure of the cervical joints, i.e., multiple ruptured ligaments.

In 1991, Dvorak et al. reported on normal intervertebral rotations, translations, and locations of centers of rotation in the cervical spine in 44 healthy subjects. They added a new parameter, the ratio between translation and rotation, which may be useful for clinical diagnosis.

In 1994, Panjabi et al. reported on 3-dimensional flexibility of the cervical spine in fresh C4-C7 cadaveric specimens. They reported average ranges of motion of 8.3° in flexion and 7.2° in extension. This movement decreased with an external fixator.

In 1994, Holmes et al. reported on cervical ranges of motion from full flexion to full extension from C2 to C7 in 78 normals and 50 Chinese cervical myelopathy subjects. Chinese subjects had similar movement patterns to Western subjects, but with slightly less movement.

In 2001, Lin et al. reported on normal movements in flexion and extension in 75 normal subjects. For normal flexion-extension movements, they stated that “nearly all the intervertebral differences of angular displacement were less than 7 degrees, and those of translation were less than 0.06 mm.”

**Rotation Angle Analysis**

In 1978, Penning may have been the first to report on a “templating” method that became a common method of measuring segmental rotational instabilities. Using cervical flexion and extension radiographs, he would place the flexion film on top of the extension film. He would superimpose C7 on each film, then he would draw posterior tangents on C6 in the extended position and on C6 in the flexed position. He would intersect these posterior tangents on C6 to get a total angle of movement of C6 during flexion-extension relative to C7 (Figure 2).

**Figure 2.** Penning’s Flexion-Extension Templating. In 1978, Penning reported on a method to determine the maximum flexion-extension angle of movement of cervical segments C2 through C7. In this example, by superimposing C7 on both views, posterior tangents on C6 in extension and flexion provide a total angle of rotation of C6 on C7 ($R_x^{C6-7}$).
Penning would, in sequence, do this “ Templating” for each vertebra, i.e., C6, C5, C4, C3, and C2. Penning also attempted to measure the “axis of movement” by locating a finite rotation center (FRC) for each cervical segment compared to the segment below. This analysis has often been incorrectly termed an “IAR”. IAR is “infinitesimal” axis of rotation and requires a continuous function in calculus, where as FRC uses perpendiculars from lines connecting like points on a “Finite” number of vertebral positions (i.e., one flexion position/view and one extension position/view).

In 1985, Mayer et al reported on a computerized method to superimpose vertebrae for Templating on flexion-extension views. They stated that time and errors are minimized by utilization of this new computer method.

In 1993, Dvorak et al. reported on a computer-aided method to determine cervical instability in 64 patients, divided into 3 groups, degenerative changes, radicular signs, and whiplash trauma. Calculating segmental motion parameters, such as rotations, translations, and centers of rotation, they stated that (1) hypo-mobility was significant at C6-C7 for the degenerative and radicular groups, (2) hyper-mobility in upper and middle cervical levels for the trauma group, and (3) locations of the centers of motion were shifted in the anterior direction in the trauma group compared to healthy populations.

### Reliability of Templating on Flexion-Extension Views

In 1988, 59 adults, 28 healthy adults and 31 patients, were examined by functional CT by Dvorak et al. The Penning method of measurement was found to be more reliable than the Buetti-Bauml method. They recommended that the flexion-extension radiographs be taken in a passive way, and not active, when comparing to normal values.

In 1989, Lind et al studied the range of motion of 70 healthy subjects in maximal flexion-extension and maximal lateral flexions. Radiographs were analyzed on a digital tablet linked to a computer. The intra-observer error was $\pm 1.8^\circ$.

In 1999, Schops et al reported on a reliability study of Penning’s Templating method (i.e., functional radiographic analysis of the cervical spine in flexion and extension) as a screening method for segmental instability. Five MDs measured angles of segmental mobility on 20 patients and 20 normal subjects. For segments C3/C4, C4/C5, C5/C6, and C6/C7, the correlation between 5 reviewers showed good to excellent results ($0.6 < \text{Pearson’s } r < 0.8$ for good, and $r > 0.8$ for excellent). The selectivity of $p \leq 0.05$ and $p \leq 0.01$ was sufficient to distinguish patients from healthy subjects.

### Reliability of Patient Positioning

In 1989, Lind et al studied the range of motion of 70 healthy subjects in maximal flexion-extension and maximal lateral flexions. The range of motion was measured with a compass placed on the subject’s head. The intra-observer error was $\pm 6^\circ$ for positioning.

Ordway et al. compared dynamic films to two other methods of measuring end-range of motion of cervical flexion, extension, protraction, and retraction. They determined that because end-range cervical flexion and extension include contributions from the upper thorax, true cervical motion must be measured from an internally referenced, or landmark-based methodology. This includes radiography so as long as the data to be extrapolated from the dynamic films are relative to the patient’s anatomy on the film (i.e. C2 vs. C7 tangent) and not related to the edge of the film (i.e. atlas plane line to horizontal). Alternatively, if the horizontal
or vertical is required, then the patient’s upper thorax should be fixed or standardized to minimize the upper thorax contribution.

**Pediatric Uses of Cervical Flexion-extension Views**

In 1993, White et al. reported on 17 pediatric patients with Downs syndrome. They stated that measurement of the atlas-dens interval is the radiographic standard for identification of patients, with Downs syndrome, who are at high risk for neurologic injury from spinal cord compression. They used MRI, extension plain radiographs, and lateral flexion radiographs. They stated that neural canal width is a better predictor of potential spinal cord compression than atlas-dens interval or clivus-posterior odontoid process distance.

In 2005, Pitt and Thakore reported on a review of 51 papers (32 from Medline and 19 from Embase) concerning utility of flexion/extension views of cervical spines in children with neck injuries. They determined that “Best Evidence” came from just three studies. They stated that if the neutral static cervical spine radiograph is normal, then flexion-extension cervical spine radiography is unlikely to be abnormal.

**Diagnostic Capabilities**

The flexion-extension stress films are useful in determining antero/retro-listheses, hypo/hyper-mobility, evidence of instability, aberrant motion at levels other than C0/C1-C7/T1, articular fixation, or other disabilities of the articulations of the head and neck. The usefulness of the ‘dynamic study’ is critical when one considers that a normal appearing neutral lateral cervical view does not exclude ligamentous injury. In fact, the determination of soft tissue and diskoligamentous injuries using plain cervical spine radiographs is poor. Additionally, it has been found that slight displacements or other subtle, yet significant findings from static lateral films which are indicative of more severe pathology, are often initially overlooked or so-called, ‘hidden’. This is why use of stress films are encouraged especially after trauma such as whiplash or polytrauma or to fully appreciate effects of degeneration, muscle spasm, aberrant intersegmental mechanics, and areas vulnerable to focal stress.

Cervical spine dynamic studies often correlate with findings from MR. For example, as mentioned previously, White et al. found good agreement when measuring neural canal widths on x-ray with that found on Down’s patient’s corresponding MRI.

In 2002, Giuliano et al. reported on 200 subjects, 100 normal’s versus 100 cervical spine trauma cases. They reported that the normal range of motion was 50° ± 6.5° in flexion and 60° ± 6.5° in extension. They found loss of lordosis in 4% (4/100) of normal’s and 98% (98/100) in the patient group. They reported finding 2% (2/100) of normal’s had asymptomatic disc herniations, while disc herniations were observed in 28% (28/100) in the patient group. They reported that normal subjects showed a stepwise segmental motion pattern that started at C1-C2 and transmitted to the lower cervical segments, while trauma patients differed from this normal pattern.

**Validity**

**Sagittal Plane Cervical Spine Instability**

Different studies indicate different criteria for spinal instability. One study indicates 1.5 – 2.0 mm of translation is clinical instability in live humans. Subluxation greater than 2 mm in men 18 to 40 years of age may be a useful variable for further study as an indicator of
ligamentous injury. However, current scientific thought is that a segmental translation of 3.5mm or more on a neutral lateral cervical or flexion/extension radiographs is evidence of ligamentous instability. It must be bourne in mind that this 3.5 mm considers a 30% magnification factor and thus the ‘true’ value would be 2.7mm. See Figure 3A for sagittal plane translation measurement. It should be noted that such translations when greater than 1.5 mm and found on a neutral lateral cervical are considered to be abnormal; this is a common misconception.

On flexion/extension radiographs, the combined total value of flexion added to extension range of motion for the lower cervical levels (C2-C7) should have a total segmental rotational movement less than 20°; greater than 20° is suggestive of ligamentous instability. It must be noted that more than 11° in one direction (either flexion or extension) at one segment is indicative instability.

On the neutral lateral cervical radiograph and/or flexion extension radiographs, two more radiological signs, acute kyphotic segmental angulation and ‘gapping’ of the spinous processes, are indirect evidence of ligamentous damage. Biomechanical studies have determined that a segment should not be flexed by more than 11° relative to the segment below using segmental Cobb (endplate) lines. However, studies using posterior body lines, have found that kinking (kyphosis) of 10° or greater is the limit and/or fanning of the spinous processes of 12mm or greater. For example, Griffiths et al found that a 10° angle or greater on the lateral cervical radiograph (flexion and/or neutral) had good sensitivity and specificity in differentiating a motor vehicle injured cohort from normal controls. Figure 3B shows segmental endplate and posterior body lines for an instability assessment.

Cervical injury should be classified as "major" if the following radiographic and/or CT criteria are present: displacement of more than 2 mm in any plane, wide vertebral body in any plane, wide interspinous/interlaminar space, wide facet joints, disrupted posterior vertebral body line, wide disc space, vertebral burst, locked or perched facets (unilateral or bilateral), "hanged man" fracture of C2, dens fracture, and type III occipital condyle fracture.

Often, the upper cervical region is not fully assessed for instability on flexion/extension radiographs. At least 3 distances should be measured in the upper cervical spine on flexion/extension radiographs for an instability analysis. See Figure 3C for upper cervical translation measurements.

Instability check list for cervical spine flexion/extension radiographs (Figure 3A-C):

1. Combined flexion/extension range of motion greater than 20° (C2-C7),
2. Segmental flexion or extension angle greater than 10-11°,
3. Vertebral body translation of 2.5-3.5 mm or more on flexion/extension,
4. Decreased anterior disc height,
5. Increased posterior disc height,
6. Interspinous space greater than 12 mm,
7. Clivus to dens distance of greater than 4-5 mm,
8. Posterior C2 dens relative to anterior C1 posterior ring less than 13 mm,
9. Atlanto-dental interspace of greater than 4 mm.
Before Penning’s 1978 publication, “Templating” flexion-extension views was taught in Radiology courses at some Chiropractic Colleges. In 1985, Henderson and Dorman reported on normal values, instability, and functional blockage for cervical motions on flexion and extension views. Regardless of Chiropractic Technique, many doctors evaluate dynamic lateral cervical films to ascertain more data on the cervical region to help determine more and less appropriate care options. For example, stress films may be used to identify hyper-mobile joints that may dictate adjusting to areas other than the affected joint complex, or hyper-mobile segment that translates into the canal upon extension would be a contraindication for certain treatment techniques utilizing only an extension moment applied to the cervical spine.

Dynamic flexion-extension studies may also be used for pre and post-treatment evaluation; i.e. a quantitative improvement in the global/segmental range of motion or a qualitative improvement in the dynamic function of the neck.

**Figure 3A-C.** In A, sagittal translation is shown of juxtapositioned vertebra. This measurement should not exceed 3.5 mm accounting for a 30% magnification. In B, two methods of segmental angulation measurement are shown. For the Cobb lines, the measurement should not exceed 11°; while for the posterior body lines, the measurement should not exceed 10°. In C, 3 translation measurements are shown for stability assessment of the upper cervical spine. Measurement A is between the superior tip of the dens and the anterior aspect of the foramen magnum (clivus), this should be between 4-5 mm. Measurement B is the atlanto-dental interspace, this should not exceed 4 mm in adults. Measurement C is the spinal canal sagittal diameter between the posterior aspect of the dens and the anterior aspect of the posterior ring of C1, this should not be less than 13 mm. *Adapted from Panjabi et al* and *White and Panjabi.*
References


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B. Thoracic Views

10. AP Thoracic Radiographic View

RECOMMENDATION

The AP Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, IV, V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

Chiropractors have been taking radiographic images of the human spine since 1910, just 15 years following the invention of x-rays by William Roentgen. The human thoracic spine is viewed in the frontal or coronal plane on radiographs using either the anteroposterior (AP) or posteroanterior (PA) direction. The AP/PA Thoracic radiographic view can be taken with the patient standing (erect) or supine. It is customary for the chiropractor to take these films in an erect, weight-bearing position (Figure 1) as opposed to the supine positioning that is more prevalent in a hospital setting.

Usually, the AP/PA Thoracic radiographic view is taken with the tube and grid cabinet distance at 40 inches. The grid cabinet, or bucky, is vertically positioned such that the top is approximately two inches above the C7 spinous process. The central ray is centered to the cabinet. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical configuration of the thoracic spine. We will review the most common of these markings and measurements and discuss the reliability and validity of such evaluation and outcome assessment techniques.

Figure 1. Standing patient position for AP thoracic spine radiographic view.
Many Chiropractic Techniques require mensuration of angular rotations and linear distances on radiographs to assist in the direction of treatment for a particular patient. The angles and distances are ascertained by means of the construction of lines drawn on the AP/PA Thoracic radiograph. In regards to the Chiropractic adjustment, the measurements obtained may dictate how the patient is positioned for adjusting, where the adjutive force is applied, what line of drive is used, etc... The adjustment can be manual, instrument assisted or by drop table means. In addition to the different corrective forces applied to the thoracic spine through the spinal adjustment, other means of correction have been proposed that are within the scope of practice in most areas, including spinal traction and exercises. Furthermore, many of these chiropractic “techniques” require that a post treatment x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment.

**Reliability of Line Drawing Methodologies**

Cobb Method: The most commonly reported method of measuring displacement of the AP/PA thoracic spine from normal is called the Cobb method. The Cobb method was first described in 1948 for the evaluation and quantification of scoliosis deformity.\(^5\) (Figure 2).

Kuklo found that most examiner error when producing these lines and angles occurs when identifying the two end vertebra.\(^14\) However, there is minimal magnitude of error even when different levels are selected. This was found to be true because the endplates are nearly parallel when it is most difficult to determine the proximal and distal end vertebrae.\(^4,14,21,38\) The Cobb angle is produced by first constructing lines along the superior endplate of the superior end-vertebra and the inferior endplate of the inferior end-vertebra, as shown in Figure 2. Then, perpendiculans are constructed to each of these lines such that they intersect forming the “Cobb angle”. The same protractor and other measuring devices, such as a ruler, should be used when evaluating films to reduce potential error, as described by Morrissy.\(^21\)

Because of the potential for examiner error, the reproducibility of producing the Cobb angle has been studied extensively, with inter-observer variability between 0.84°- 8.0° and excellent intra-examiner reliability.\(^4,6,14,21,37,38\) However, as stated above, when the end vertebra are standardized (as in clinical practice), the errors are extremely small.\(^14,37\) For example, Lantz, a chiropractor, demonstrated a minimal 0.6° margin of error for intra-examiner test-retest reliability.\(^14\) Wilson et al found a SEM of 0.84° for 38 examiners measuring 1 PA x-ray.

![Figure 2: Cobb angle measurement of thoracic scoliosis. The “Cobb angle” is produced from the intersection of perpendiculans from the endplates of the superior and inferior end-vertebrae.](image)
Risser-Ferguson Method: See figure 3. The Risser-Ferguson method of analyzing the frontal plane of the thoracic spine is less commonly reported in the literature. In an opinion paper, Kittleson and Lim argued that the Risser-Ferguson method should be used for curves under 50° and the Cobb method for those curves over 50° due to validity issues. Stokes et al found that the Risser-Ferguson method of analysis produces an average angle that is 1.35 times less than the Cobb angle.

At least two investigations have reported examiner errors and reliability for the Risser-Ferguson method. Both investigations reported good to excellent examiner reliability for the Risser-Ferguson method.

Rib Vertebral Difference (RVAD): See Figure 4. Mehta first described a method to measure axial rotation of the apical segment in a thoracic scoliosis in 1972. The method requires identification of the apical vertebra. The associated ribs are identified. A line is drawn from the midpoint off the neck of each rib to the midpoint of the head of each respective rib. A perpendicular is drawn to the middle of either the upper or lower endplate of the selected thoracic vertebra. The intersection of each rib line with the perpendicular vertebral line is the rib vertebral angle (RVA). The difference of the concave measurement and the convex measurement is the rib vertebral angle difference (RVAD). The reliability of the markings was not discussed by Mehta in the original article.

However, in 1997, McAlindon and Kruse demonstrated intra-observer error of 4.4° and inter-observer error of only 3.6°. Four observers measured the angle of 50 radiographs. This procedure was repeated a second time 2 days later and a third time 2 days after the second.
Clavicle angle: See Figure 5. The clavicle angle is defined as the angle produced by the intersection of a horizontal line and a line connecting the highest two points of each clavicle. This is described as a means of assessing the proximal thoracic scoliosis and shoulder height.

Reliability of Patient Positioning

Several investigations have been performed on the test re-test reliability of patient positioning for the AP/PA full spine or sectional AP thoracic measurements. Problematically, many authors have misrepresented the scientific evidence on this topic and offer their Class V opinion that radiographic positioning is a significant source of error for AP/PA thoracic spine measurements. For example, Capasso claimed that difference in the curve of up to 17° can occur between an AP standing radiograph compared to a that obtained with a positioning device. A review of pertinent studies provides a different conclusion.

In 1978, Dawson et al took repeated AP full spine x-rays on 60 scoliosis patients in the upright and the scoliosis chariot (SC) positioning device on the same day. Fourteen subjects had 2 scoliosis chariot x-rays exposed within 5 minutes of each other (3 total x-rays in each of these
Average differences in Cobb angle between the AP full spine and SC view were 3.4°-7.5° (increasing as curve magnitude increased). The difference in 2 repeated SC views were all within ± 3°. The authors concluded that SC views for scoliosis were more repeatable. However, repeated AP full spine views were not performed on the same subject. Therefore, this study shows that as long as the clinician uses the same positioning procedures, then high examiner reliability will be found. This study was misinterpreted by Capasso.

In 1982, Desmet et al took AP and PA full spine x-ray views of 78 scoliosis patients with an average time of 5-15 minutes between radiographs. Strong correlation between curve measures on AP vs. PA full spine films was found; r = .960. The PA view demonstrated a mean increased curve of 1.71° compared to the AP view. In 5/128 curves a 9°-13° increase, in 19/128 curves a 6°-8° increase, and in 4/128 curves a 6°-8° decrease on the PA film was found. The difference in curve values is due to projection of endplates on PA vs. AP films. However, this study does not indicate that positioning is a source of error as long as the same procedures are followed.

In 1995, Kohlmaier et al took 2 AP full spine x-rays (standing and in a positioning device) of 100 scoliosis subjects. They concluded that the balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards. However, Kohlmaier et al did not actually investigate the repeatability of the same position on each subject therefore no conclusions can be drawn.

In order to investigate positioning errors, Sevastikoglou and Bergquist took 17 frontal plane radiographs of 2 scoliosis skeletons: neutral, rotation up to 10° left/right and 5 cm elevation or depression of the tube height. Two examiners assessed the curves using the Cobb and Riser-Ferguson methods. They found little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson’s method and 2.06° ± 1.09° for Cobb’s method. This information was misinterpreted and inaccurately reported by Capasso et al.

Pruijs, et al, investigated the repeatability and reliability of thoracic, thoracolumbar and lumbar Cobb angle measurements by studying two sources of error: the production of the radiograph and drawing/measuring the lines/angles. Regarding the production of the radiographs, the investigators compared serial radiographs in patients who underwent surgical spinal fusion for scoliosis and therefore had a fixed spinal curve. They discovered that the production of the series of radiographs produced a standard deviation in the Cobb angle of only 3.2°. This is often less than the standard error of measurement, as discussed previously in some studies. In other words, the measurement method may not be sensitive enough to detect any ‘true’ differences in the curve caused by positioning.

Based on the above review, it is the consensus of the PCCR panel that positioning procedures for exposing the AP/PA thoracic radiographs are reliable as long as the same procedures are followed on initial and repeat films.

**Diagnostic Capabilities**

The AP and PA thoracic views have been used to evaluate many anatomical structures visible on the film. The thoracic spine, ribs, clavicles, sternum and scapulae are bony structures visible on the frontal plane radiographs of this area. Soft tissue structures, such as the heart and lung fields, are also visible on these films.
Multiple investigations have found correlation and predictive validity of the AP/PA Thoracic radiographic alignment to a variety of health related conditions. A review of these investigations is provided below. The AP/PA Thoracic view has the following correlations:

1. Cobb angle magnitude can predict scoliosis progression,
2. Magnitude of curve displacement correlates to rate of osteoarthritis,
3. Magnitude of displacement correlates to health, pain, and disability,
4. RVAD predicts tendency of progression in infantile scoliosis,
5. Clavicular angle is predictive of shoulder height.

**Cobb Validity**

The magnitude of scoliosis as determined by the Cobb angle on plain films has been shown to be predictive of progression of the scoliotic curve. In a study of 85,627 children screened for scoliosis, it was shown that in those with scoliotic curves > 30° Cobb angle, the incidence of progression (increasing Cobb angle > 5° from visit to visit) was 48%. For curves 10-20° the rate was lower at 11.9% to 20%, respectively.

Richter, et al, studied the rate of osteoarthritis in a group of 100 scoliosis patients with an average age of 19 years and ranging from 12-30 years old; this group did not include anyone with so-called “age-related” osteoarthritis of the spine. The authors found that, “37% of curves less than 20° had osteophytes, and this increased to 53% of curves greater than 40°”. Subjects were compared to a control group and were found to have a higher incidence of degenerative changes (P < .01). Two observers graded the degenerative changes and there was a close inter-observer correlation. In addition, ten of the films were repeated, without knowledge of previous assessment, by both observers demonstrating good intra-observer reliability. Weinstein, in a 50-year follow-up of untreated scoliosis, showed that 95% of the scoliotic spines demonstrated significant degenerative changes.

Misalignment of the thoracic spine in scoliosis patients, as measured by the Cobb angle, has also been associated with different Health-Related Quality of Life (HRQL) outcome scores. Wilson, et al, found that coronal measures of thoracic curve, including the Cobb angle, were negatively correlated with the following parameters of the Scoliosis Research Society (SRS) outcome assessment questionnaire: Total Pain (r = .22, P < .001), General Self Image (r = .23, P < .001), General Function (r = .18, P < .003) and Total SRS score (r = .22, P < .001). As curve magnitude increase, the scores decreased, i.e., worsened health scores, thus the negative correlation. Asher et al, also found that, as a group, pre-operative (untreated) thoracic curves were associated with lower General Function scores (r = .52, P < .001), Subtotal Score (r = .43, P < .0089) and pain.

In 2002, Freidel, et al, found that, compared to the age-matched general population norms, juvenile females with scoliosis were unhappier with their lives (P = .001), had more physical complaints (P < .001), had lower self esteem (P = .01) and higher depression scores (P = .021) than their peers. Adult patients reported more psychological (P < .001) and physical impairment (P < .001) than compared to the population norm. In a 2005 Japanese study assessing untreated scoliosis patients with the SRS outcome assessment questionnaire, the scores of Pain (r = -.33, P < .0001) and General Self Image (r = -.25, P < .0024) had a significant inverse correlation with thoracic curve Cobb angle. The authors also note that, “patients with a thoracic
curve Cobb angle of more than 40° had lower outcome scores than those with a thoracic curve Cobb angle less than 40°.28

A review of the literature reveals a relationship between Cobb angle magnitude and risk of progression, development of osteoarthritis and different outcome scores of health-related quality of life, including depression, self-esteem, being unhappy with life, and physical impairment. Again, clinically the Cobb angle is measured on plain film radiographs through manually constructed line-drawing technique. This method is widely used in both the chiropractic and medical professions. It is important to note that a recent survey of the intention of chiropractors to manage scoliosis showed that, “in general, the respondents would provide 6 months of ‘intensive’ chiropractic therapy, then follow the patient for 4 years (near skeletal maturity).”8 More than 80% of the respondents would use diversified technique, which relies upon radiographic spinal “listings”; while 87% would use “exercises” in their treatment.8

RVAD Validity

The rib vertebra angle difference between the concave versus the convex apical level has been shown to have predictive validity in assessment of tendency of progression in infantile scoliosis. A difference of 20° or more is indicative of an 80% chance of progression. Conversely, a RVAD less than 20° is 80% likely to resolve.18 Some of the progressive cases had initial Cobb angles as small as 12°. The only presenting signs in infantile scoliosis may be postural distortion. The RVAD is the only method reported in the literature, to our knowledge, that has such high predictive validity for the progression of infantile and juvenile scoliosis. If radiographs are not taken on the young patients, who present with no “red flags” other than postural distortion, they could suffer early mortality associated with early onset progressive idiopathic scoliosis.3

Clavicular Angle Validity

Kuklo reported on 112 patients assessed and treated for proximal thoracic scoliosis and resultant shoulder imbalance.13 The clavicular height was the only radiographic variable measured that was predictive for accuracy of shoulder height (measured as the soft tissue shadow on the film) in subjects treated surgically for scoliosis in three out of the four groups studied (P = .0009, .0193, .0716 and .0007).13

Outcome Investigations

Level I Studies:

In a randomized controlled-comparison clinical trial, Plaugher et al.22 investigated the efficacy of Gonstead chiropractic adjusting technique with patients demonstrating essential hypertension and spinal subluxation. The mean change in diastolic blood pressure was -4 in the chiropractic care group. One of the variables in determination of location and type of adjustment was spinal misalignment as measured on AP plain film radiographs.

Level II Studies: No Level II studies could be found.

Level III Studies: No Level III studies could be found.
Level IV Studies:

Alcantara et al\(^1\) reported on a 74-year-old geriatric female patient with complaints of mid thoracic and low back pain. Radiographic evaluation revealed acute compression fracture of T8, as well as subluxation “listings”, including levels T5 and T8, as measured from the AP image of the thoracic spine. Comparative radiographs were obtained at 4 ½ weeks, demonstrating correction of the T5 and T8 levels. The patient was adjusted a total of 25 times from initial to the comparative x-ray.

In another case study a 63-year-old male patient presented with myasthenia gravis.\(^2\) Primary subluxations were identified on the AP radiograph image at the C7 and T4 spinal levels. The patient was adjusted based upon these spinal listings. The myasthenia gravis symptoms were essentially resolved through subluxation correction. The patient was adjusted 33 times then told to come in 1-2 times a month or on an as-needed basis. The patient reported only mild thoracic and low back pain.

Morningstar et al,\(^2^0\) reported on the effectiveness of Pettibon methods with a case series of 19 scoliosis cases. Pre-treatment radiographs were taken on each patient and Cobb angles were measured. Post-treatment radiographs were taken 4-6 weeks following their intervention and comparative Cobb angles were constructed. There was an average 17° reduction in the Cobb angle.

Gilmour et al\(^1^0\) reported on the successful management of patient with a 35° left convex thoracolumbar scoliosis treated using Pettibon corrective procedures. Initial and follow-up outcome measures included a Borg pain scale, a Functional Rating Index, a balance test, and radiographic analysis. After six weeks of treatment, the post treatment radiograph revealed a 20° left convex thoracolumbar scoliosis (15 reduction in the curve), as well as decreases in the Borg pain scale (6 to 2) and Functional Rating Index score from 18/40 to 7/40.

Joy et al\(^1^1\) reported on the successful management of 3 patients with idiopathic or scoliosis secondary to Scheuermann’s disease. Patients were treated with spinal adjustments and head/body weighting exercises for 12 weeks. A reduction in Cobb angles of 13°, 8°, and 16° was found in the 3 cases respectively over 12 weeks of treatment.

Adjunctive Procedures Used by Chiropractic Clinicians

Eighty Six percent (86%) of chiropractors report that they would incorporate exercises in their treatment plan for a patient with idiopathic soliosis.\(^8\) Miyasaki\(^1^8\) studied the effect of an exercise forcing the thorax into forward flexion. This exercise was evaluated for its effect on apical rotation and the lateral flexion deformity while they were in the Milwaukee brace. They found that thoracic Cobb angles were larger while standing passively in the Milwaukee brace as compared to the smaller Cobb magnitude while performing the thoracic flexion exercise.

In 1983, Mehta reported on the use of lateral thoracic shifting exercises for scoliosis patients.\(^1^6\) She reported, that her exercises “are comparable with those reported by braces or electrospinal stimulation”. The post treatment Cobb angle had either decreased or remained unchanged in 71% of the patients. For a curve to be “progressive” it must increase in severity by 5° or more in one year. The group considered “most at risk” for progression averaged about 1° worsening per year over the 1.9 years they treated the patients. Mehta states, “thoracolumbar and low thoracic curves respond best to the side-shift, lumbar curves less so, particularly when there is an acute take-off at L5”.\(^2^8\)

In 1999, another group of clinical researchers demonstrated that active “side-shift” exercises were found to have a promising effect on Cobb angle in idiopathic scoliosis patients.\(^7\)
The subjects ranged in age from 10-15 years old and had initial Cobb angles ranging 20-32°. The subjects performed their side shift exercise regime for more than 4 months. The side-shifting group showed only a 2° increase of Cobb angle after 4 months. They compared these results to a matched historical brace cohort group, which showed a 2° decrease in Cobb angle. Also of importance is the non-compliance of each group. The side-shift group only had 4.5% non-compliance, while the brace group had resulted in 24.2% of the original group not in compliance. This demonstrates the tendency for the adolescent aged patient’s preference for non-bracing treatment.

Three dimensional exercise therapy for scoliosis has been utilized on an inpatient setting in Germany at the Katharina Schroth Clinic. In one study, published in 1992, Weiss reports on the effectiveness of the program on 107 scoliosis patients. Exercises designed to reduce the curves were used as was what the author calls “rotational breathing”, which is supposed to increase inspired air to the concave areas of the chest by selective contraction of the convex areas of the trunk with the goal of lengthening and mobilizing related soft tissue areas. The average Cobb angle of the primary curve decreased from 43° to 40° and the secondary curve decreased from 28° to 26°. Greater than 97% of the primary curves and over 99% of the secondary curves either decreased in magnitude or remained the same. The group in this study was relatively mature, average age of 21.6 years, and thus at a lower risk for progression.

To test whether positive results could be obtained for patients considered at high risk for progression, in 1997, Weiss et al studied 181 patients at high-risk for progression, that is an average age of 12.7 years, average Cobb angle of 27° and average Riser sign of only 1.4. Follow-up radiographs were obtained at an average of 33 months and Cobb angles were measured. At 33-month follow-up the average Cobb angle was 29°, only 2° worse. Over the course of almost three years, one would expect a “progressive” curve to increase by at least 15°. This team of clinical researchers has reported similar success in various studies.
References


11. Lateral Thoracic Radiographic View

RECOMMENDATION

The Lateral Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, D.

Introduction

In radiography of the thoracic spine, the lateral thoracic radiographic view is generally one of two primary views. Care should be taken to insure that several structures are visible from the upper thoracic spine superiorly to the thoraco-lumbar junction (T12-L1) inferiorly. In the majority of cases, a lateral lower lung field filter (T7-T12) is needed in order to adequately visualize the entire thoracic spine.

In chiropractic analysis, the lateral thoracic view should be taken in the upright standing position at the standard tube distance of 100 cm (40 inches) with the central ray located approximately at the T6-T7 disc level. For lateral thoracic radiographs, the patient’s arms must be positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height\(^1\), by holding arms out almost 90° in front grasping a stand,\(^2\) by folding the hands on top of the head,\(^3\) or by folding the arms on the chest placing the hands in the clavicular fossae.\(^4\)

Since chiropractic clinicians are interested in the alignment of the patient’s individual spine, the self balance position seems appropriate to ascertain the patient’s unique subluxation alignment. The patient’s abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the ‘self balance positioning’ of a patient with hands on a rest at iliac height, hands and arms straight out in front grasping a pole, hands on top of the head, and with hands in the clavicular fossae in their neutral resting posture.

Reliability of Measurement Methods

The lateral thoracic radiograph measurements include the total curve measurements at a various upper, middle, and lower thoracic levels, sagittal balance (flexion/extension and sagittal translation) of the upper versus lower thoracic levels, segmental thoracic kyphosis values, and thoracic vertebral body wedge angles to assess deformity from fracture or other pathology. These methods have been measured in a multitude of different ways on lateral thoracic radiographs. The Harrison Posterior Tangent, Cobb, Centroid, and length versus width have all been subjected to examiner reliability investigations.\(^5\)\(^-\)\(^14\) Harrison et al.\(^5\) investigated the inter- and intra-examiner reliability of the Harrison Posterior Tangent (HPT), Cobb, and Centroid methods for assessment of thoracic kyphosis. Excellent examiner reliability, low standard errors of measurement, and small absolute differences of observers’ measurements were found. See Figures 2-4.
Carman et al\textsuperscript{6} and Jackson et al\textsuperscript{7} have investigated the reliability of the Cobb Method for measurement of thoracic kyphosis. Collectively these studies indicate that measurement of the lateral thoracic radiographic alignment has excellent observer reliability for a variety of methodology.\textsuperscript{5-14}

\textbf{Figure 1 A-D.} Self balance position for the lateral thoracic radiograph. In A, the patient assumes the ‘self balance position’ and then the arms are folded on the chest placing the hands in the clavicular fossae on the ipsilateral sides. In B, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In C, the patients arms are flexed nearly 90° at the shoulder and the hands are placed on a pole. In D, the arms are abducted, elbows flexed, and hands folded on the head.

\textbf{Figure 2.} The Harrison Posterior Tangent (HPT) method. In A, HPT lines are drawn along the posterior body margins of each vertebra from T1-T12 to measure the segmental contributions to thoracic curvature. In B, HPT lines are drawn along the posterior body margins of T1 & T12, in order to measure the total curve angle. In C, the vertical alignment of T1 centroid is compared to T12 centroid for sagittal balance assessment. The HPT method for measuring lumbar lordosis has high reliability, low standard errors of measurement, and small absolute differences of observers’ measurements.
Figure 3. The Cobb Method can be drawn with 4-lines or 2-lines and from a variety of different levels. In A, segmental cobb angles are drawn along each inferior endplate to measure the segmental contributions to thoracic kyphosis. In B & C, construction of the total kyphosis curve angle is shown using T1 superior endplate and T12 inferior endplate lines. These methods have good to excellent inter and intra examiner reliability.

Figure 4 A-D. In A-D, the Centroid method for total curve angle and segmental curvature is shown. However, the Centroid method cannot actually measure true segmental alignment as it requires three vertebrae to construct one angle. These methods have good to excellent inter and intra examiner reliability.
Repeatability of Patient Positioning

At least five studies have performed repeat radiographs of the lateral thoracic spine in the same subject.\(^{1,7,12,15,16}\) Without exception, these five investigations clearly demonstrate that lateral thoracic alignment on follow-up radiographs is repeatable even when films were taken by different examiners months or years apart.

Stagnara et al\(^1\) stated, "For subjects undergoing clinical and X-ray examinations at intervals of five to ten years, and where no growth or pathologic deformation factors are to be taken into account, the clinical and X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees, provided the position is clearly stipulated."

Jackson et al\(^7\) took initial and follow-up lateral full-spine radiographs in 20 volunteers and 20 low back pain patients taken 66 months and 2 weeks apart, respectively. Very little variation in the thoracic kyphosis from T1-T12 was found between the 1st and follow-up x-ray with ranked correlation coefficients of \(r = 0.81\) for volunteers and \(r = 0.79\) for patients.

Singer\(^{12}\) compared 22 pairs of in vivo and post mortem lateral thoracic films. The time difference between the films ranged from 3 days to 77 months. No statistically significant differences were found in the magnitude of thoracic kyphosis using the Cobb method and a computer assisted curvature measurement.

Milne and Williamson\(^{15}\) reported no significant change in radiographically determined thoracic kyphosis measurements for initial and average 5 year follow-up in 261 elderly subjects.

Using a statistical model with Cartesian coordinates representing the path of the vertebral bodies of the thoracic and lumbar spine in the sagittal plane, Beck and Killus stated, “...several X-rays of the same individuals furnished reproducible results, even though they were taken years apart.”\(^{16}\)

Diagnostic Capabilities

When properly performed, the lateral thoracic radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, and spinous processes should all be visualized. The lateral thoracic view provides the chiropractic clinician with valuable information including:

1. Total thoracic kyphosis,
2. Segmental contribution to kyphosis,
3. Breaks in Georges’ line or sagittal plane translation of the posterior vertebra and spinous lamina junction for a general stability analysis,
4. Vertebral body wedge angles for pathology and fracture analysis,
5. General sagittal balance alignment of the upper vs. lower ribcage,
6. Stages of disc, ligament & vertebral body degenerative pathologies,
7. Spinal canal dimensions,
8. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed and found correlation and predictive validity of the lateral thoracic radiographic alignment to a variety of health related conditions including:

1. acute and chronic back pain;\(^{17-19}\)
2. psychological distress due to cosmetic appearance of deformity;\(^{20,21}\)
3. hyper cervical lordosis;\(^{12,22}\)
4. stress/strain relationships and degenerative joint disease (DJD),\textsuperscript{23-26}
5. impaired rib cage expansion during respiration,\textsuperscript{27}
6. altered shoulder alignment & gleno-humeral pathology,\textsuperscript{28}
7. physical disability & functional impairments,\textsuperscript{18,29-32,49}
8. risk of deformity progression and vertebral body fractures,\textsuperscript{20,25,33}
9. development of vertebral body wedge deformities,\textsuperscript{50,51}
10. risk of scoliosis development & progression,\textsuperscript{34,35}
11. organ prolapse,\textsuperscript{36}
12. longevity.\textsuperscript{15,37-39}

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the lateral thoracic radiographic alignment and the conditions in the above 12 categories is of adequate quality. Thus, we conclude that the lateral thoracic radiographic alignment has positive correlation to and predictive validity for these 12 categories.\textsuperscript{12,15,17-39,49-51}

**Outcome Investigations**

Several outcome investigations have been performed using a variety of conservative procedures aimed at restoration of the normal thoracic kyphosis in a variety of patient pain and health disorders.\textsuperscript{21,40-48} The majority of these reports combine exercise, bracing, and/or passive 3-point bending traction with postural awareness in a multimodal treatment approach to reduce sagittal plane thoracic deformities. Collectively, these reports indicate that patients benefit from a multi-modal physical and chiropractic treatment approach aimed at improvement and/or restoration of an abnormal sagittal thoracic spinal alignment.\textsuperscript{21,40-48}

**Level I Studies:** No Level I studies using chiropractic intervention could be located.

**Level II Studies:**

In a small clinical trial, chiropractic adjustments combined with rehab procedures compared with rehab procedures alone was found to be superior in the reduction of thoracic hyper-kyphotic curvature.\textsuperscript{40}

**Level III Studies:** No Level III studies using chiropractic intervention could be located.

**Level IV Studies:** No Level IV studies using chiropractic intervention could be located.
References


32. You J, Gieck J, Yoder E. Does simulated dorsal kyphosis alter lower limb kinematics, kinetics, and emg patterns during gait?


C. Lumbar Views

12. AP Lumbar Radiographic View

RECOMMENDATION

The AP Lumbar Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II, IV, V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The human lumbar spine and pelvis is commonly viewed in the frontal (coronal) plane for assessment of structural alignment. The AP Lumbar radiographic view can be taken with the patient standing (erect) or supine recumbent. It is customary for the chiropractor to take these films in an erect position (Figure 1) as opposed to the supine recumbent positioning that is more prevalent in a hospital setting.

This view is taken with the tube and grid cabinet distance at 40 inches. The central ray is adjusted vertically to approximately 1-2 inches below the top of the iliac crest (level of L3). The grid cabinet, or bucky, is vertically positioned to accommodate the central ray. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical configuration of the lumbar spine and pelvis on the frontal plane radiograph. We will review the most common of these markings and measurements and discuss the reliability and validity of such evaluation and outcome assessment techniques.

Figure 1. Positioning for AP Lumbar Radiograph.
The patient is positioned with the pelvis centered to the bucky. The central ray is aimed at the L3 level.
Some authors advocate the use of the PA Lumbar radiograph in order to reduce radiation exposure levels to ‘sensitive’ organs as well as improved visibility of certain lumbar vertebral landmarks. The information presented in section VII, however, indicates that fears of increased radiation exposure are without scientific merit. Furthermore, the increased abdominal size of some patients makes the PA Lumbar radiograph impractical. Still either the PA or AP view would be acceptable pending the clinician’s preference.

Many Chiropractic Techniques use measurements on the AP lumbar/pelvic view to help dictate the course of treatment for the patient. This determination may include how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of drive will be. The adjustment can be manual, instrument assisted or by drop table means. In addition to the different corrective forces applied to the lumbar spine through the spinal adjustment, other means of mechanical correction have been proposed, such as spinal traction. Furthermore, these techniques require that a post treatment x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment.

**Reliability of Line Drawing Methodology**

Cobb angle: The most common method of measuring the deviation of the lumbar spine from normal on this film is called the Cobb method. The Cobb method was originated by Cobb, a medical physician, in 1948. Lines are constructed along the superior endplate of the superior end-vertebra and the inferior endplate of the inferior end-vertebra; perpendiculars are constructed to each of these lines such that they intersect forming the “Cobb angle”. See Figure 2.

There are several sources of error in the production of the Cobb angle, but selection of the end vertebra of the scoliosis is the most significant. Using different protractors to measure the same angle has been shown to produce varying results. Therefore, the same protractor and other measuring devices, such as a ruler, should be used when evaluating films.

The reproducibility of manual construction of the Cobb angle has been studied extensively, with variability between 0.84° - 8.0° and excellent overall reliability. Zmurko, et al, studied the intra- and interobserver error of Cobb angle measurements on digital versus traditional radiographs. The films were evaluated by four examiners on two occasions two weeks apart. The authors found that, “There was no statistical difference in the mean error index, the variability in choosing the end vertebra on successive measurements, between the digital and traditional groups”. Similarly, there was no significant difference in the intraobserver or interobserver variance between the digital and traditional groups. They concluded that, “Digital radiographs are comparable to the use of traditional radiographs for following patients with adolescent idiopathic scoliosis”.

Gonstead Measurements: In Gonstead technique, endplate ‘wedge angles’ are used to assess juxtaposition segmental subluxation as well as overall Cobb angle alignment. Plaugher et al, studied the reliability of Gonstead radiographic analysis for several variables of static radiological alignment of the lumbar spine/pelvis. They found that all variables had high inter- and intra-examiner reliability, (p<0.001).
Risser-Ferguson Method: The Risser-Ferguson method (See Figure 3) is another means of quantifying scoliosis magnitude, but is reported much less in the literature. Stokes et al.\textsuperscript{54} suggested using the Risser-Ferguson method in situations where the Cobb angle measurement is technically difficult or non-representative. They\textsuperscript{54} found a ratio of 1.35 to 1 for Cobb angles to Risser-Ferguson angles on AP radiographs (review Figure 2).\textsuperscript{54} Similarly, Harrison et al.\textsuperscript{55} found a ratio of 1.6 to 1 when comparing the T12-L5 Cobb angles to Modified Risser-Ferguson angles.
Chiropractic Biophysics: Modified Risser-Ferguson Method: In 2 separate investigations, CBP technique evaluated the reliability of their method to evaluate spinal and sacral alignment from true vertical on the AP lumbar radiograph with line drawing methods.\textsuperscript{16,40} The 2-dimensional center of mass (2-DCOM) was determined and best-fit lines constructed forming a lumbodorsal (LD) angle in the mid lumbar spine. The resultant LD angle is measured in degrees. The angle of the sacral base relative to horizontal (HB) was evaluated. The angle of the distal “lumbar” line was measured relative to the sacral base superior endplate line resulting in the lumbosacral or LS angle. The final variable was the perpendicular distance of the T12 2-DCOM from a vertical axis line constructed from the center sacral tubercle (Tx\textsubscript{T12}). Thirty seven radiographs were analyzed by 3 examiners two times each.\textsuperscript{40} The methods demonstrated ICC values (assuming nested factors) representing good to excellent for all parameters measured. The repeated measures ANOVA resulted in ICC values of 0.71 for the HB angle, 0.97 for the LD angle, 0.83 for the LS angle and 0.95 for the Tx\textsubscript{T12} linear distance.\textsuperscript{40} In a second analysis of the Modified Risser-Ferguson method with ICC’s assuming random crossed factors, Harrison et al\textsuperscript{16} showed that the same data actually produced higher reliability (greater than 0.88) for all measures except the measures of the sacral base (0.61-0.78).

Reproducibility of Patient Positioning
Plaugher et al\textsuperscript{30} in 1993, studied the repeatability of AP lumbopelvic radiographs taken 1 hour apart in one group and after 18 days in another. Paired t-tests were performed to observe differences between the two radiographs. They found that there was no statistically significant difference between the films for all measures performed.
In a 2005 study, Harrison, et al,\textsuperscript{15} evaluated the test re-test reliability of AP lumbar radiographs in a control group comprised of 37 subjects who did not receive care. Initial

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{modified_risser-ferguson_method.png}
\caption{Modified Risser-Ferguson method. The “Harrison angle” is calculated by finding the projected center of mass of each vertebra and constructing 2 best-fit lines. This center of mass is located at the mid-posterior vertebral body. It is found on AP x-rays by bisecting the vertebral body from the side at the narrow waisted margins, then taking half way to the spinal laminar junction.}
\end{figure}
radiographs were obtained and follow-up radiographs were taken an average 8.7 months later. The measurements on the two AP lumbar radiographs were essentially unchanged, including the HB angles, LD angles, LS angles and $T_{12}^L$ measurements. These measurement comparisons take into consideration the repositioning of the patient almost 9 months following the initial radiograph.

Prujs et al. showed that when one examiner analyzed 3 serial radiographs of ten scoliosis patients, the variation of the Cobb angle was minimally affected (average of 2.2°, maximum of 7°) by the repositioning of the patient and the x-ray tube as seen on pre and post films obtained on the same patient one year apart. They state, “Apparently, subjects with established spinal deformity assume a more or less similar position each time they are subjected to X-ray examination.”

The error due to repositioning is within the range of averages reported for the interexaminer reliability of the Cobb analysis on the same radiograph. Therefore, the PCCRP panel considers the effects of repositioning to be negligible upon the measured magnitude of lumbar spine subluxations on AP/PA lumbar radiographs.

**Diagnostic Capabilities**

The AP lumbar view has been used to evaluate many anatomical structures visible on the film. The lumbar vertebra from T12-L5, sacrum, ilia, sacro-iliac joints, and distal ribs are generally visible on the radiograph. Soft tissue structures of the abdomen and pelvis are also evaluated diagnostically.

**Validity**

Multiple investigations have found correlation and predictive validity of the AP/PA Lumbar radiographic alignment to a variety of health related conditions. A review of these investigations is provided below. The AP/PA Lumbar view has the following correlations:

1. Cobb angle magnitude can predict scoliosis progression.
2. Initial apical vertebral rotation, lateral translation and L5 vertebral height relative to the iliac crest can predict adult AP lumbar curve progression.
3. AP lumbar curve subluxation magnitude predicts flexibility and range of motion.
4. Magnitude of AP lumbar subluxation/displacement correlates to rate of osteoarthritis.
5. Magnitude of AP lumbar subluxation correlates to low back pain.

**Cobb Method**

The magnitude of scoliosis as determined by the Cobb angle on plain films has been shown to be predictive of progression of the curve. In a study of 85, 627 children screened for scoliosis it was shown that, for those with scoliotic curves $>30^\circ$, the incidence of progression (increasing Cobb angle $>5^\circ$ from visit to visit) was 48%. For curves $10-20^\circ$ the rate was lower at 11.9% to 20% respectively. Pritchett, et al investigated risk factors for curve progression in patients over the age of 50 with adult onset degenerative symptomatic scoliosis. He found that patients progressed at an average of $3^\circ$ per year in 73% of the subjects over the 5-year study. The authors state, “Grade 3 apical vertebral rotation, a Cobb angle of $30^\circ$ or more, lateral vertebral...
translation of 6 mm or more, and prominence of L5 in relation to the inter-crest line were important factors in predicting curve progression”.

Magnitude of the lumbar curve patterns in adolescents with idiopathic scoliosis has been studied extensively to estimate a progression threshold magnitude. In 40-year\textsuperscript{42} and 50-year\textsuperscript{41} follow-up studies, Weinstein et al demonstrated that lumbar curves exceeding 30° Cobb angles at skeletal maturity were at high risk for continued progression. Apical vertebral rotation greater than 33% was present in all frontal plane curves larger than 30°. MacGibbon and Farfan\textsuperscript{20} and Ascani\textsuperscript{20} found similar results with regard to a 30° threshold for progression of lumbar curves of adolescent idiopathic onset. Idiopathic thoraco-lumbar curve patterns were shown to possess the most apical vertebral rotation. This increased rotation and the presence of lateral vertebral translations are indicative of progression.

The magnitude of the curve also has an inverse relationship to the degree of flexibility and coupled motions as measured on lateral bending radiographs.\textsuperscript{11,56}

Abnormal spinal displacement analysis of the lumbar spine resulting in scoliosis has been associated with low back pain. Jackson et al\textsuperscript{17} showed that the incidence of low back pain in a group of adult patients with idiopathic scoliosis was the same as an age-matched control group. However, the pain was much more severe in the group with scoliosis. Pain increased with age and Cobb angle magnitude (P < .0005). Kostuik et al\textsuperscript{18} found that in adults with scoliosis, there was a direct relationship between the magnitude of the Cobb angle and the severity of low back pain, particularly for curves over 45°. Schwab et al\textsuperscript{22} (2005) did not come to the same conclusion. However, the magnitude of the scoliosis in his subject groups was smaller. In a 1994 study,\textsuperscript{23} it was shown through retrospective analysis that scoliosis subjects had higher prevalence of low back pain than a matched group with a similar phone administered survey. Subjects were adults with adolescent onset idiopathic scoliosis. The pain in those with demonstrable Cobb angles on previous films described their pain as more continuous, generalized, intense and radiating into the extremities. They were also more restricted in their usual daily activities.

Schwab et al,\textsuperscript{38} in 2002, were able to establish predictive validity of radiological parameters, including vertebral latero-listhesis and L3 and L4 endplate obliquity angles, for self-reported pain levels.

Richter et al,\textsuperscript{35} studied the rate of osteoarthritis in a group of 100 scoliosis patients with an average age of 19 years and ranging from 12-30 years old. Therefore, this group did not include anyone with so-called “age-related” osteoarthritis of the spine. The authors found that, “37% of curves less than 20° had osteophytes, and this increased to 53% of curves greater than 40°.”\textsuperscript{35} Subjects were compared to a control group and were found to have a higher incidence of degenerative changes (P < .01). Two observers graded the degenerative changes and there was a close inter-observer correlation. In addition, ten of the films were repeated without knowledge of previous assessment by both observers demonstrating good intra-observer reliability. One study demonstrated that in 73% of subjects over the age of 50 with degenerative symptomatic lumbar scoliosis, curves progress at an average rate of 3° per year over a 5 year period.\textsuperscript{33} The average initial Cobb angle was 30°, there was significant axial rotation of the apical vertebrae, and a latero-listhesis > 6 mm. All measurements were taken on frontal plane films. In a 50-year follow-up study of untreated adolescent idiopathic scoliosis, individuals demonstrated significant spinal degeneration, with radiographically measured, latero-listhesis being a common indicator of low back pain.\textsuperscript{41}

Misalignment of the lumbar spine in scoliosis patients, as measured by the Cobb angle, has also been associated with different Health-Related Quality of Life (HRQL) parameters.
Schwab et al.\textsuperscript{37} in their 2005 study, showed no correlation between an elderly population with scoliosis and visual analog pain scale. However, those patients with scoliosis Cobb angles 10-20° had lower scores for Vitality (P<0.05) and Mental Health (P< 0.02) as compared to U.S. population norm (age 65-74 age group).

**Biomechanical Validity:**

For this type of validity, the clinician compares the spinal coupled motions on the AP Lumbar radiograph to the published results of “main motion coupled motion” performed on thoraco-lumbar postural movements. If the usual coupled motion patterns on AP lumbar radiographs are not present for a particular thoraco-lumbar posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for thoraco-lumbar movements and AP Lumbar radiographic patterns.\textsuperscript{55,57}

It is the consensus of the PCCRP panel that the quality of investigations finding a correlation between AP lumbar radiographic alignment and the conditions in the above 6 categories is scientifically sound. Thus, we conclude that the AP lumbar radiographic alignment has positive correlation and validity for these 6 categories.

**Outcome Investigations**

**Level I Studies:** No Level I studies utilizing chiropractic intervention could be located.

**Level II Studies:**

In a non-randomized clinical controlled trial, Harrison et al.\textsuperscript{15} reported on 63 patients with chronic low back pain matched to a control group with the same condition. Patients were treated with CBP methods directed at subluxation correction of the spine in the frontal plane.

Radiographs were taken initially and at final evaluation. The patients demonstrated approximately 50% structural alignment of trunk list (Tx\textsuperscript{T12}), as well as approximately 40% improvement of the LD angle and LS angles. These improvements in structural alignment were associated with improvement in self reported Numerical Rating Scale (NRS) pain level (initial avg. = 3.0, post care = 0.8). The control group did not demonstrate statistically significant change in any of the AP lumbar radiographic measurements (except a slight worsening of the Tx\textsuperscript{T12}) nor in NRS levels.

**Level III Studies:** No Level III studies using Chiropractic intervention could be located.

**Level IV Studies:**

Many well reported cases of chiropractic management of AP lumbar subluxations, including lumbar scoliosis, have been described.\textsuperscript{1-3,6,9,14,21,22,27,28,32,58-64} The treatment employed in these cases was almost always dictated by the appearance of the scoliosis on the frontal plane image. The primary outcome measure is the Cobb angle as measured manually on the x-ray, and pain and disability scores. Several examples of these studies follow.

In a 2004 case report, Alcantara et al.\textsuperscript{3} reported on chiropractic treatment of a 23-year old male patient with low back pain associated with subluxations and a malgaigne-type fracture of the pelvis. The authors utilized Gonstead method of analysis and treatment, including
radiographic line drawing analysis of segmental subluxation misalignment. The patient was seen only 5 weeks following the acute fracture of the pelvis. Subluxations were treated at spinal levels of L2 and L5, as well as the left ilium. The patient was cared for daily for 2 ½ months. Initial follow-up radiographs were obtained at 1 month demonstrating improvement/correction of the subluxation listings. His pain was significantly reduced and he was able to return to work as a dry cleaner. The patient was seen periodically for the following 13 years.

Alcantara et al² report on a 2-year old girl who presented with her mother for symptoms associated with recent onset myasthenia gravis following a motor vehicle collision. Adjustments were provided to the cervical and sacral spines based in part upon specific spinal listings measured form AP images of the spine. The toddler responded well to care and was free of symptoms following 5 months of care. For the first 3 ½ months of care the girl was adjusted 2-3 times a week. Comparative x-rays were taken and evaluated with reported improvement.

Alcantara et al¹ also described similar results in a patient with subluxation, low back pain and epileptic seizures.

Berry et al⁵⁸ reported on the successful management of a patient suffering from low back pain and leg pains with disc herniations. The patient was previously treated with surgical decompression including a laminectomy and was unresponsive to traditional chiropractic manipulation. The patient was treated with CBP methods to correct spinal subluxations of the AP lumbar radiographic view, lateral cervical view, and the head-thorax and thoraco-lumbar abnormal postures. Following 9 months of Chiropractic rehabilitative care with multiple re-examinations, the patient’s disability score on the Oswestry Chronic Low Back Pain Disability Questionnaire indicated that the patient improved during treatment from 74% to 24%; while spinal and postural subluxations were corrected to near normal limits.

In a retrospective case series, Harrison et al⁵⁹ reported on the reductions of thoraco-lumbar scoliosis in five patients using the Chiropractic Biophysics treatment methods. Thoraco-lumbar scoliosis was significantly reduced in all patients as were NRS and Oswestry disability scores. Significantly 4/5 subjects had long-term follow-up showing stability of the AP lumbar radiographic subluxation reductions.

Colloca and Polkinghom⁹ reported on two patients with Ehlers-Danlos syndrome who sought chiropractic care for disabling musculoskeletal pain. The patients were treated according to Activator Methods Chiropractic Technique and Chiropractic Biophysics methods. In one patient (43-year old male) the self-reported pain and disability improved and upon repeated radiographic examination, lumbar Cobb angle improved from 5° to zero. The anatomical leg length inequality improved from 12 mm to zero as well.

Morningstar and Joy²⁷ described the treatment of scoliosis in 3 cases using Pettibon body weighting system. AP radiographs were obtained and measured Cobb angles were reported (35°, 22° and 37°). Treatment consisted of manipulation and exercises. Home care was a major component of the treatment. Curve direction as measured on the AP films dictated course of care. Post treatment radiographs were obtained. Cobb angles reduced to 13°, 8° and 16°, respectively.

Morningstar²⁸ also reported on the effectiveness of their methods in a case series of 19 subjects with scoliosis. Pre-treatment radiographs were taken on each patient and Cobb angles were measured. Post-treatment radiographs were taken 4-6 weeks following their intervention and comparative Cobb angles were constructed. There was an average 17° reduction in the Cobb angle.
Adjunctive Procedures:

In a recent survey of the intention of chiropractors to manage adolescent idiopathic scoliosis, 86% of responding chiropractors reported that would utilize exercises in their treatment plan. In our review of the literature, we found many studies investigating the effectiveness of exercises alone, and in combination with other procedures, in the management of lumbar scoliosis.

Mooney and Brigham found that scoliotic patients had asymmetrical axial rotational strength of the thorax, which occurs at the Thoracolumbar junction. Ten out of 12 subjects had weakness of the muscles on the concave side of the curve. They conducted a 4-month strength-training program using Med-X strength training equipment. Sixteen of the 20 subjects demonstrated curve reduction.

Miyasaki studied the effect of their thoracic flexion exercise on apical rotation and the lateral flexion deformity on patients while they are in the Milwaukee brace. They found that the thoracic flexion exercise significantly reduced the deformity as compared to standing passively in the Milwaukee brace with no exercise. Manually constructed Cobb angles were used for evaluation of the curve magnitude. If the curve pattern resulted in a “decompensation” of the spine, as is commonly seen on AP radiographs in patterns involving the thoracolumbar or lumbar spine, then Miyasaki recommended lateral shifting of the trunk with respect to the pelvis while in the brace. The shift is performed toward the thoracolumbar or lumbar curve convexity, without regard to the presenting posture of the patient. This particular procedure was recommended mainly for primary lumbar curves, for this is where the action of the maneuver occurs.

Mehta was the first to report the use of lateral shifting exercises as a primary intervention in the correction of scoliosis. She recommend using a mirror so the patient can see the mirror image of the lateral shifting. She reported that her results “indicate that they are comparable with those reported by braces or electrospinal stimulation”. The patients had an initial Cobb angle between 15° and 42°. The post treatment Cobb angle had either decreased or remained unchanged in 71% of the patients. Over the course of 1.9 years, the group considered “most at risk” for progression averaged only 2.0° increase of curvature. Although this may not sound satisfactory, remember that for a curve to be considered progressive it must increase in severity by 5° or more in one year. Therefore, the most at risk group which was most likely progressive only worsened by 2° versus the 10° expected during the “watchful waiting” period recommended by many medical authorities. Mehta states, “thoracolumbar and low thoracic curves respond best to the side-shift, lumbar curves less so, particularly when there is an acute take-off at L5”.

Another recent study by den Boer et al, in 1999, demonstrated that active “side-shift” exercises were found to have a promising effect on Cobb angle in idiopathic scoliosis patients with an initial Cobb angle ranging from 20-32°, ages 10-15 and in those who performed the therapy for more than 4 months. The patients participated in 10-12 half-hour sessions once a week to learn the side-shift procedure. Patients were instructed to perform the shift as often as possible each day. They received a refresher course once a month. The side-shifting group showed only a 2° increase of Cobb angle after 4 months. They compared these results to a matched historical brace cohort group, which showed a 2° decrease in Cobb angle. Also of importance is the non-compliance of each group. The side-shift group only had 4.5% non-compliance, while the brace group had resulted in 24.2% of the original group not in compliance. This demonstrates the tendency for the adolescent aged patient’s preference for non-bracing treatment.
German clinical researcher Hans Rudolf Weiss reported success utilizing a 3-dimensional exercise program in the reduction of scoliosis. In one study, published in 1992, he reports on the effectiveness of the program on 107 patients. Exercises designed to reduce the curves were used (called “rotational breathing”). The average Cobb angle of the primary curve decreased from 43° to 40° and the secondary curve decreased from 28° to 26°. Greater than 97% of the primary curves and over 99% of the secondary curves either decreased in magnitude or remained the same. The group in this study was relatively mature, average age =21.6 years, and thus at a lower risk for progression. To test whether positive results could be obtained for patients considered at high risk for progression, in 1997, the same group studied 181 patients with an average chronological age of 12.7 years, average Cobb angle of 27° and average Risser sign of 1.4. By current knowledge, this represents a high-risk group. They used the same exercise program as in the 1992 study and performed a follow-up at an average of 33 months. The group as a whole (N=181) demonstrated an initial Cobb angle of 27° and at 33-month follow-up it measured 29°.

Similarly, in 2003, Weiss et al performed an age, sex and curve magnitude matched, controlled clinical trial, which demonstrated that their methods reduce the incidence of progression in children with idiopathic scoliosis. This group has reported similar successful scoliosis intervention in several other clinical studies.

**Summary**

A systematic review of the literature reveals that frontal plane imaging of the lumbar spine, in either the anteroposterior (AP) or posteroanterior (PA) directions is a common diagnostic procedure in the medical, chiropractic and physiotherapy professions. Radiographic line drawing procedures used for spinal displacement analysis is also common in all professions. Line drawing methods are widely used for scoliosis assessment, that is, global or regional subluxation, as well as for determination of intersegmental subluxation by Chiropractic clinicians. Repositioning patients while producing frontal plane lumbar radiographs is repeatable. The biomechanical information obtained from these radiographs is reliable and valid and is used in the determination of care in chiropractic, physiotherapeutic and medical settings.


13. **Lateral Lumbo-pelvic Radiographic View**

**RECOMMENDATION**

The Lateral Lumbo-pelvic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.


**PCCRP Evidence Grade: Clinical Studies = B, C, D.**

**Introduction**

In radiography of the lumbar spine, the first to be obtained is generally the lateral lumbo-pelvic view. Care should be taken to insure that several structures are visible from the lower thoracic spine superiorly to the tops of the femur heads inferiorly. In many cases, a lateral lower lung field filter is needed in order to adequately visualize the entire lumbar spine.

In chiropractic analysis, the lateral lumbar should be taken in the upright standing position at the standard tube distance of 100 cm (40 inches) with the central ray located approximately at the L3-L4 disc level. For lateral lumbo-pelvic radiographs, the patient’s arms are positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height, by folding the hands on top of the head, or by folding the arms on the chest placing the hands in the clavicular fossae.

Since chiropractic clinicians are interested in the alignment of the patient’s individual spine, the self balance position seems appropriate to ascertain the patient’s unique subluxation alignment. The patient’s abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the ‘self balance positioning’ of a patient with hands on a rest at iliac height, hands on top of the head, and with hands in the clavicular fossae in their neutral resting posture.

**Reliability of Measurement Methods**

The lateral lumbo-pelvic radiograph measurements include the sacral base to horizontal, sagittal translation or balance, pelvic tilt, pelvic morphology, segmental sagittal plane translation for retrolisthesis and anterolisthesis, segmental rotational lordosis, and global lordosis measures. These variables have been measured in a multitude of different ways on lateral lumbo-pelvic radiographs. The Harrison Posterior Tangent, Cobb, Centroid, Trall, and Pelvic Radius have all been subjected to examiner reliability investigations.

Harrison et al and Troyanovich et al investigated the inter- and intra-examiner reliability of the Harrison Posterior Tangent (HPT) method for assessment of lumbar lordosis. Excellent examiner reliability, low standard errors of measurement, and small absolute differences of observers’ measurements were found. See Figure 2.
Harrison et al, Polly et al, Chernukha et al have investigated the reliability of the Cobb Method for measurement of lumbar lordosis. Here, the superior or inferior endplates of the vertebra is used to construct lines. See Figure 3.

The Centroid Method for measurement of lumbar lordosis has been studied in two separate reports and found to have excellent examiner reliability. The tangential radiologic assessment of lumbar lordosis (TRALL) uses an apex at the greatest depth of lordosis. This methods has been found to have excellent inter and intra-examiner reliability.

The Pelvic Radius Technique for measuring lumbo-pelvic alignment. This method depends upon construction of the pelvic radius (PR) and has been found to have excellent inter and intra-examiner reliability. Figure not shown.

Collectively these studies indicate that measurement of the lateral lumbo-pelvic radiographic alignment has excellent observer reliability for a variety of methodologies.

**Figure 1 AB.** Self balance position for the lateral lumbo-pelvic radiograph. In A, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In B, the arms are ab ducted, elbows flexed, and hands folded on the head. In C, the patient assumes the ‘self balance position’ and then the arms are folded on the chest placing the hands in the clavicular fossae.
Figure 2. The Harrison Posterior Tangent (HPT) method. In A, HPT lines are drawn along the posterior body margins of L1-L5 to measure the magnitude of the curve. In B, HPT lines are drawn along the posterior body margins of all segmental levels, T12-S1, in order to measure segmental angles termed relative rotation angles (RRA’s). In C, the sacral base to horizontal, pelvic tilt, and sagittal translation balance are shown. The HPT method for measuring lumbar lordosis has high reliability, low standard errors of measurement, and small absolute differences of observers’ measurements.4,5

Figure 3. The Cobb Method can be drawn with 4-lines or 2-lines and from a variety of different levels. In A, the 4-line Cobb angle from superior endplate of L1 and the inferior endplate of L5. In B, the 2-line Cobb angle from the inferior endplate of T12 to the superior sacral endplate of S1. In C, segmental Cobb angles constructed with lines drawn on the inferior endplates of T12 through L5 and the superior sacral base. These methods have good to excellent examiner reliability.4,6,7
Repeatability of Patient Positioning

At least four studies have performed repeat radiographs of the lateral lumbar spine in the same subject.\textsuperscript{1,10,12,17} Without exception, these four investigations clearly demonstrate that lateral lumbo-pelvic alignment on repeated radiographs is repeatable even when films were taken by different examiners months or years apart.

For example, Jackson et al\textsuperscript{10} reported ranked correlation coefficients of 0.93-0.96 for lumbar lordotic measurements for initial and follow-up x-rays of 20 volunteers and 20 low back pain patients. Harrison et al\textsuperscript{17} analyzed initial and repeat lateral lumbar x-rays in 30 control group subjects where follow-up x-rays were collected after a mean of 9 months. All angles and distances changed less than $1^\circ$ or 1 mm and all P-values were not statistically significantly different (P>0.05). Stagnara et al\textsuperscript{1} stated, “For subjects undergoing clinical and X-ray examinations at intervals of five to ten years, and where no growth or pathologic deformation factors are to be taken into account, the clinical and X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees, provided the position is clearly stipulated.”

Saraste et al\textsuperscript{12} investigated the differences between radiographs of 125 spondylolytic patients in the recumbent and standing positions with respect to vertebral slipping and lumbo-sacral lordosis. There were only minor projectional and interobserver measurement errors in the variables describing vertebral size and lumbosacral lordosis, which make these variables suitable for radiographic assessment at repeated examination.

Diagnostic Capabilities

When properly performed, lateral lumbo-pelvic radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, spinous processes, sacrum, and femur head/acetabular landmarks should all be visualized. The lateral lumbo-pelvic view provides the chiropractic clinician with valuable information including:

1. Total lumbar lordosis,
2. Segmental lumbar lordosis,
3. Breaks in Georges’ line or sagittal plane translation of the posterior vertebra and spinous lamina junction for a general stability analysis,
4. Sacral base angle to horizontal,
5. Pelvic tilt,
6. Pelvic morphology,
7. General translation alignment of the ribcage relative to the pelvis,
8. Stages of disc, ligament & vertebral body degenerative pathologies,
9. Stage of articular process degeneration,
10. Spinal canal dimensions,
11. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed, finding correlation and predictive validity of the lateral lumbo-pelvic radiographic alignment to a variety of health related conditions including:

1. acute and chronic low back pain,\textsuperscript{9,10,18-34,67-70}
2. health quality of life and disability measures,\textsuperscript{30-33}
3. sick leave and 1st time occurrence of low back pain \cite{33,34}.
4. stress/strain relationships & degenerative joint disease (DJD) \cite{35-42}.
5. sciatica and radiculopathy \cite{43}.
6. spondylo-listhesis development, pain, & progression \cite{44-49}.
7. range of motion and segmental motion patterns \cite{50,51}.
8. post surgical patient pain and disability outcomes \cite{52,53,72}.
9. risk of deformity progression \cite{54-56}.
10. hip osteo-arthritis \cite{70,71} and
11. post-surgical hardware failure \cite{73}.

Oppositely, a few investigations have found that the lateral lumbo-pelvic alignment measurements do not correlate to and predict the findings in the above 11 categories \cite{57-63}. However, many of these investigations have been found to be internally flawed and critiques of these studies has been performed \cite{64-66}. It is the consensus of this panel that the number and quality of investigations finding a correlation between lateral lumbo-pelvic radiographic alignment and the conditions in the above 11 categories is superior to the few negative correlation studies. Thus, we conclude that the lateral lumbo-pelvic radiographic alignment has positive correlation and predictive validity for the 11 categories \cite{9,10,18-56,67-73}.

**Outcome Investigations**

Several outcome investigations have been performed using a variety of chiropractic procedures aimed at restoration of the lumbar lordosis and improvement in the sagittal lumbar alignment in a variety of patient pain and health disorders \cite{17,74-79}. In at least 2 investigations no improvement in lumbar lordosis was found following chiropractic adjustment procedures \cite{79,80}. However, 1 study \cite{79} found reductions of the retrolisthesis subluxation of the lumbar vertebra and neither study utilized a multi-modal approach \cite{79,80}.

**Level I Studies:** No Level I studies could be found.

**Level II Studies:**

In a non-randomized clinical control trial adding the chiropractic procedure of extension traction to traditional chiropractic lumbar spine adjustment methods, Harrison et al \cite{17,74} found consistent increases in lumbar lordosis and reductions in chronic pain intensity in treated patients with chronic low back pain compared to no changes in a control group. Importantly, at 1.5 year follow-up, the pain and subluxation improvements were stable in the treatment group.

**Level III Studies:**

Even though no change in lumbar lordosis was found following Gonstead adjustments to the lumbar spine, the study by Plaugher et al \cite{79} identified a measurable improvement in segmental retro-listhesis at follow-up lumbar radiography.

**Level IV Studies:**

In a case series of 3 males with degenerative flat back syndrome (kyphotic lumbar spine with anterior sagittal balance), Harrison and Bula \cite{75} found that a combined chiropractic approach using lumbar adjustments and extension traction improved the lumbar lordosis and decreased pain and disability.
Paulk et al\textsuperscript{76} presented a case report of failed conservative management of low back pain, leg pains and impairments due to disc herniations and loss of lordosis. Following Chiropractic Biophysics adjustments and lumbar extension traction, the pain and impairments improved and the lumbar lordosis was re-established to near normal alignment.

In a modified version of the supine 3-point bending lumbar traction unit developed by Harrison et al\textsuperscript{17,74-76}, Troyanovich and Buettner\textsuperscript{77} reported an improvement in lumbar lordosis in a patient with D.I.S.H.

Morningstar et al\textsuperscript{78} reported on the successful management of thoracic pain and impairment due to lumbar kyphosis and anterior head translation. Re-establishment of the lumbar lordosis was found utilizing Pettibon technique procedures.

Collectively, these reports\textsuperscript{17,74-79} indicate that patients benefit from combined (multi-modal) chiropractic technique interventions aimed at improvement and/or restoration of an abnormal lateral lumbo-pelvic spinal alignment.
References


8. Chen YL. Centroid measurement of lumbar lordosis compared with the Cobb technique. Spine 1999; 24(17):1786-90.


14. Lumbar Flexion and Extension Radiographic Views

RECOMMENDATION

The Lateral Lumbar Flexion/Extension Radiographic view is indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. These views should be obtained when a patient has suspected instability, sustained lumbar trauma, pain upon sagittal plane movement, and/or for kinematic evaluation. This radiographic view has reliability, validity, biomechanics and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels III and V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics and Validity Studies = a.

Introduction

The lateral flexion and extension studies represent a means to acquire more in-depth analysis of lumbar spine function and pathology, especially of hypo- and hyper-mobile segments. Hyper-mobile being an increase in segmental rotation angles about the horizontal axis and/or an increase in AP or PA segmental translations. These views are typically done immediately following a neutral lateral and AP views, or can be done as follow up views to aid in further analysis and patient care, essentially for segmental instability. The lumbar flexion-extension views are often termed “dynamic views” but, in fact, are end-range static stress x-rays. (See Figure 1) These views have been done in the sitting or standing positions.

Flexion-extension studies may also be used for pre and post-treatment evaluation; i.e. an improvement in the global/segmental range of motion or an improvement in the dynamic function of the back. Evaluation of segmental translations and rotation angles in the A-P or P-A directions have been evaluated by a variety of ways.

Flexion-extension views are taken with the tube and grid cabinet distance at 72 inches. The central ray is adjusted vertically to approximately 1-2 inches below the top of the iliac crest (level of L3). The grid cabinet, or bucky, is vertically positioned to accommodate the central ray. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical movements of T12, L1, L2, L3, L4, L5 and the sacrum/pelvis on these flexion and extension radiographs. We will review some common methods and measurements. Additionally, we discuss the reliability, validity, and outcome assessment studies.

Reliability of Measurement Method

Flexion-extension X-rays, with maximal extension and flexion of the lumbar tract, represents the most widely used technique and a reliable and valid method to estimate sagittal segmental lumbar motion. In essence, the exact same measurement methods as used on the neutral lateral lumbar x-ray are used and thus the same reliability studies apply (See view #13 above).
There are two methods of measuring lumbar lordosis that have been carried over to flexion-extension measurements in the lumbar spine, end plate analysis and posterior tangent analysis. In 2001, Harrison et al reported that the Cobb method and the Harrison Posterior tangent method were highly reliable and had the ability to create and measure segmental angles of rotation.

However, the usual method of measuring segmental lumbar spine rotation mobility is by comparing posterior tangents. Using hand superimposition of the same segment on lumbar spine radiographs in flexion and extension (e.g., L5), one compares the posterior tangents at the posterior vertebral body margin for the vertebra immediately above (e.g., L4) for a segmental angle of total flexion-extension. Often this method lacks precision due to differences in the cortical outline of the vertebral bodies in flexed and extended positions. The introduction of digitizing vertebral margins on radiographs and digital image processing have created the possibility of computerized superimposition (‘matching’) of digital vertebral body images by means of image registration.

In 1990, Putto and Tallroth studied reliability of two methods of measuring segmental motion on flexion-extension films. Their new examination method yielded better mobility of the spine than any method earlier described. For the two lowest vertebral spaces, L4-5 and L5-S1, the new method implied significantly greater angular mobility and total angular mobility.

Figure 1. Lateral Lumbar Flexion and Extension Radiographs. The patient is positioned with the pelvis centered to the bucky. The central ray is aimed at the L3 level. The 14x17 cassette may have to be rotated 90° in order to have T12 appear on the film in flexible persons. In A, lumbar flexion is shown. In B, lumbar extension is shown. Note: the L1 compression fracture and the retrolisthesis apparent at L1 and slightly at L2.
between L2-S1 than a previous method. Intra- and interobserver errors accounted for were acceptable and the accuracy of the measurements sufficient for clinical work.

In 1991, Dvorak et al. reported normal angles of rotation for 41 healthy adults in passive motions. A graphic construction and a computer-assisted method were used to measure lumbar segmental rotations. The graphic construction and the computer-assisted methods were found to be equally reliable, but the computer method could also yield measurements of translations.

In a 1992 study, Panjabi et al. determined errors in motion parameters due to spinal level, radiographic quality, and errors in performing measurements with two digitizing instruments. The error (2 x SD) ranges were (1) ±1.25° for rotations, (2) ±0.86° for translation of the inferior posterior body corner, and (3) ± 4.3 mm for the coordinates of the center of motion. They stated that both the spinal level and the radiographic quality affected the magnitude of errors in all motion parameters.

In 1994, Tallroth et al. studied the reliability of extension-flexion radiography by analysing intra-observer and inter-observer variations in measurements of 30 patients with established L5-S1 spondylolisthesis. The overall consistency and concordance were good. The variations in intra-observer and inter-observer readings were similar.

In 2005, Penning et al. reported on a computerized method on digital radiographic images. To check accuracy and convenience of the new method, two computer program experts performed five image registration measurements of the five lumbar motion segments in five consecutive flexion-extension studies. Pathologies observed on these studies were old lumbar fracture, spondylolytic spondylolisthesis and degenerative anterolisthesis. “For comparison an experienced radiologist performed the same repeated measurements with the manual superimposition method. Measurement error of the image registration method proved to be significantly smaller than that of the manual superimposition method. The image registration method proved to be more convenient because the whole procedure from import of the image data to display of the measurement outcomes lasted 2-3 min compared to 3-6 min for the superimposition method.”

In 2005, Fritz et al. studied 49 subjects who had flexion-extension lumbar radiographs and who had low back pain. Repeatability of radiographic variables was reported to be high and 28 subjects had radiographic instabilities, while reliability of clinical variables ranged from moderate to good.

Reliability of Patient Positioning

Bronfort and Jochumsen determined that least variation in measuring motion in the lumbar spine via flexion-extension views was the sagittal plane standing position.

Diagnostic Capabilities

The lumbar flexion-extension stress films are useful in determining the following biomechanical information:

1. Antero-listhesis and retro-listheses (instability),
2. Lumbar Kinematics at sagittal end range position,
3. Hypo/hyper-mobility or segmental articular fixations,
4. Evidence of instability,
5. Rotational instability.
Validity

Several attempts have been made to measure segmental range of motion in the lumbar spine during flexion-extension in order to gather data for the diagnosis of instability. In 1989, Hayes et al. obtained flexion-extension lumbar views in 59 asymptomatic individuals undergoing routine pre-employment examination. Results indicate that there is 7 to 14 degrees of angular motion present in the lumbar spine but a large range of values exist so that norms of angular motion cannot be more precisely defined. There are 2 to 3 mm of translational motion present in the lumbar spine at each intervertebral level. Twenty percent of this study's asymptomatic subjects had 4 mm or more translational motion at the L4-5 interspace and at least 10% had 3 mm or greater motion at all levels except L5-S1.

In 1991, Dvorak et al. attempted to determine the clinical validity of segmental measurements on lumbar flexion-extension radiographs for identifying the need for surgical intervention. In 101 adults, divided into 5 classifications of pathologies and physical conditions, it was found that all of the patient groups exhibited significant hypo-mobility, spread equally among all lumbar levels, in comparison to normal group motions. Athletes were found to have hyper-mobility. Using segmental motion on the flexion-extension radiographs, they could not discriminate between the patient groups.

In 1993, Lin et al. reported on lateral functional radiographs of flexion and extension using Putto's method in 89 normal subjects. For translation changes, 2 mm is regarded as acceptable in most cases at levels from L1 to L5, but not at the level of L5-S1 where the average translation change was only 0.4 mm. The differences in the absolute translation value among different positions were not statistically significant (p = 0.064).

In 1994, Lin et al. measured segmental motion in 89 subjects. From extension to flexion, all of the intervertebral rotations approached 0 degrees (straight spine in flexion) relative to the lordotic position; the translations changed from slightly retro-listhetic to zero displacement. Using L3-L4 as a baseline for calculating the intervertebral differences in flexion, all of the rotational differences were less than 1.5 degrees, except at L5-S1, which remained 5 degrees. The mean translational difference was less than 0.6 mm, except at L5-S1, where it remained 1.5 mm.

In 1994, Cardin (a chiropractor) evaluated the active lumbar flexion-extension radiographs of low back pain patients and asymptomatic volunteers. The radiographs were evaluated to assess differences between the two groups using intersegmental angular and translational measurements. Average differences for angular and translational ranges of motion between groups were found, with a lower range of motion affecting the low back pain group. Subjective definitions of hypo and hypermobility were also offered to evaluate their prevalence within the samples.

In 1996, Inufusa et al. studied the canal and IVF diameters in flexion-extension. They reported that sagittal computed tomography scans showed that extension decreased all the foraminal dimensions significantly, whereas flexion increased all the foraminal dimensions significantly. The translational changes were associated with the bulging of the disc and the presence of traction spurs.

In 1996 using flexion-extension in 3 subjects, Fennell et al. reported that flexion of an intervertebral disc tends to be accompanied by posteriorly directed migration of the nucleus pulposus within the disc. Extension tends to be accompanied by an anteriorly directed migration.

In 1998, Zander and Lander reported that in 10 of the 33 patients (12 levels), the CT myelogram underestimated spinal stenosis, as compared with the upright flexion-extension.
myelogram. In 5 levels, stenosis of 70% or more seen on flexion-extension myelography was measured as 50% or less on CT myelography.

In 1998, Wildermuth et al\textsuperscript{30} reported that, in 30 patients, quantitative assessment of sagittal dural sac diameters is comparable between lumbar myelography and positional MR imaging. In a selected patient population, only small changes in the sagittal diameter of the dural sac and foraminal size can be expected between various body positions, and the information gained in addition to that from standard MR imaging is limited [corrected].

In 2000, Miyasaka et al\textsuperscript{17} studied 90 adults in flexion-extension. The segmental ranges of motion, segmental flexion, and extension at every level of the lumbar spine were calculated by using functional radiographs. Besides providing normal values and segmental contributions, they reported that the iliolumbar ligaments regulate lumbosacral motion; especially flexion.

In 2001, a study considered disc degeneration and osteophyte formations on resultant segmental motions during flexion-extension. Tanaka et al\textsuperscript{28} reported kinematic properties of the lumbar spine are related to disc degeneration. Greater motion was found with disc degeneration, particularly in grades III and IV, in which radial tears of the annulus fibrosus are found. Disc space collapse and osteophyte formation as found in grade V resulted in stabilization of the motion segments.

In 2002, Pitkanen et al\textsuperscript{22} correlated degenerative spondylolisthesis at the L3-4 level and at the L4-5 level and spondylolytic spondylolisthesis at the L5-S1 level on plain films to anterior sliding instability on flexion-extension films. They also reported that retrolisthesis, traction spurs, and spondylarthrosis at the L3-4 level were statistically significant determinants of posterior sliding instability.

In 2004, using a biomechanical investigation on facet and ligament influences on lumbar segmental motions, Lee et al\textsuperscript{13} showed that lumbar ligament damage and facet damage greatly affects segmental motion on flexion-extension films. The effect of the facetectomy on the motion segment is insignificant under flexion. In extension, unilateral facetectomy and resection on the contralateral facet markedly alters the rotational motion and flexibilities as well as coupled motions. Also, unilateral complete facetectomy with resection of less than 100% on contralateral facet generates high facet load.

In 2004, Wong et al\textsuperscript{32} studied 100 healthy volunteers, including 50 men and 50 women, in lumbar flexion and extension. Lumbar flexion-extension was assessed with an electrogoniometer and videofluoroscopy simultaneously. Intervertebral flexion-extension of each vertebral level was calculated. Radiologic images of the lumbar spine were captured during flexion-extension in 10 degrees intervals. A linear-linked pattern of the motions was observed in different genders and age groups. No statistically significant difference in the pattern of motion was found between genders. However, statistically significant difference in the slope of curves was found at all lumbar levels in subjects whose age was 51 years or older.

In 2004, Iguchi et al\textsuperscript{11} stated that some previous authors consider flexion-extension radiographs to be of little value in evaluating instability. They stated the variation of results in evaluating radiologic instability is the result of limitations in previous researchers' methods. They studied sagittal translation and angulation at the L4-L5 segment. These were measured in flexion-extension films in 1,090 outpatients with low back and/or leg pain. The symptoms of four groups with and without 3-mm translation and with and without 10 degrees angulation were compared for all the patients and for 280 age-matched patients using a scoring system. The age-matched patients were followed up for 4.6 years. Results showed that patients with $\geq$ 3mm translation had significantly lower scores, indicating a limitation in their daily activities due to
pain, than patients < 3 mm translation. They reported no differences between the groups in terms of angulation. The group with \( \geq 3 \)-mm translation and \( \geq 10 \) degrees angulation significantly demonstrated the lowest scores at both evaluations during the initial visit and follow-up. This group had been suffering from low back and/or leg pain the longest and had visited the hospital significantly more often than other groups. They stated translation of the lumbar segment has a greater influence than angulation on lumbar symptoms.

**Outcome Investigations**

Monitoring and/or evaluating differences in global and segmental motion and patterns in low back pain patients via chiropractic treatment have been done. Bronfort and Jochumsen determined that “specific manipulative therapy can objectively increase the intersegmental mobility of the lumbar spine.” In a randomly chosen group of seven patients out of an original group of 75 with chronic low back pain (CLBP), follow-up functional radiographs were obtained after a months worth of chiropractic treatment. They noted that “contrary to reports by other investigators, this indicates that this mode of treatment might be able to increase the intersegmental mobility of the lumbar spine.”
References


**RECOMMENDATION**

The AP Ferguson Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

**Supporting Evidence:** Clinical Levels I, IV, V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

**PCCRP Evidence Grade:** Clinical Studies = B, C, D and Reliability, Population, and Validity studies = a

**Introduction**

The AP Ferguson (or just Ferguson View) sacral base radiographic view was originated by Albert Bartlet Ferguson in 1939. This view was taken at a 45 degree tilt through the sacral base to eliminate the overlapping of the vertebrae. This view allows for optimal clarity of the sacral wings and pelvis. His book states that a radiological examination of the lumbosacral spine is not complete without this view.

The AP Ferguson view is taken standing with the heels directly underneath the patient’s hips/femur heads so that the legs are parallel. Their toes are lined up with overt pronation or supination removed to prevent dropping of the tibia. All pelvis rotation must be removed by centering the pubic symphysis and the S2 tubercle to remove any asymmetrical magnification projection. The central ray should be tilted cephalad through the L5 disc space (between the anterior superior iliac spine (ASIS) and the iliac crest). The degree of cephalad tilt should be measured off of the lateral view. Figure 1 depicts patient positioning and a sample radiograph.

This view requires a little more work in equipment and positioning time compared to an AP Lumbar view. The specialized equipment includes a tilt-able x-ray tube, a laser aligned x-ray frame that will ensure the cassette, tube, and floor are all level with each other. A lateral lumbar x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject’s sacral base angle. This tilt and tube height is derived from the sacral base angle to horizontal measurement in degrees from the lateral lumbo-pelvic view.

**Reliability of Line Drawing Procedures**

In the late 1800’s a number of studies were published on leg length inequality, with standing radiographs for postural analysis by Schwab and Hoskins from 1921 to 1934. There are many different methods of evaluating leg length inequality (LLI), sacral base un-levelness (SBU), and pelvic obliquity (lateral tilt). A review of the literature finds that radiographic evaluation is both valid and reliable compared to unreliable or invalid clinical (palpation of landmarks). Measurements are made on the AP Ferguson view in millimeters or degrees to analyze both the sacral base levelness and the femoral head levelness relative to horizontal.
Concerning radiographic assessment, there are several different measurements utilized to determine LLI. The two most common on the AP Ferguson are: 1. pelvic obliquity and 2. femur head level to horizontal measures. Figure 2 demonstrates the pelvic obliquity method. Both the pelvic obliquity and femur head level methods are reliable at determining LLI, but they provide different information; where the former is the measure of levelness of the sacral base and the later is a direct measure of the left versus right femur head level.

Bailey and Beckwith⁴ may have been first to draw a line along the sacral base though vertical lines extended up from the apex of the femur heads (Right Triangle Method in Figure 2A). In a reliability study with 52 radiographs and 4 examiners, Fann et al⁴⁶ found good to high Pearson correlation coefficients and percent agreement for the right triangle method. Tilley³⁷ assessed the reliability of measuring different landmarks of the pelvis for pelvic obliquity and found good reliability.

The reliability of using differences in femoral head height has been established. Studies have identified a standard error measurement of 1-3mm for radiographic assessment of left versus right femur head measures.₂₃,₃₈-₄₃

Using either of the two methods in Figure 2, the measured difference needs to be reduced by up to 25% to account for the x-ray magnification or enlargement. As an example, Juhl et al² found that the femoral head measurement were magnified between 12% and 20% depending on AP diameter of the pelvis.

**Reliability of Patient Positioning**

At least 7 separate studies have been performed on repeated AP pelvic radiographs on the same subjects with both an intra and inter day and multiple examiner methods. Without exception, excellent reliability has been found for repeated measures on repeat radiographs for LLI. Using repeated radiographic views of the same subject, Giles and Taylor⁴⁹ and Clark⁴⁰ found a standard error of repeatability of femur head measures of 1-3 mm. In both

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**Figure 1 AB.** In AB, the patient positioning for the AP Ferguson is shown with the central ray bisecting approximately the ASIS and the top of the iliac crest.
studies, there was intra and inter-rater reliability and x-rays were taken by different radiographic technicians. Similarly, Beal\textsuperscript{38} and Friberg et al\textsuperscript{41} found repeatability of femur height of 1-2mm in repeated radiographs taken from 1-30 months after the patients’ initial radiographic examination. Leppilähti et al\textsuperscript{42} examined the radiographs of 15 subjects taken at 2 separate intervals on the same day. A mean error of repeated measures for femur head differences were 1.0mm, with a range of 0-2mm and a correlation coefficient of 0.96.

In 105 patients with chronic low back pain, Friberg\textsuperscript{44} retook pelvic radiographs in order to analyze the consistency of anatomical leg length inequality and pelvic rotation about the gravity axis. Radiographs were repeated after an interval of 2 weeks to 3 years. The mean error between repeat x-rays was 0.7 mm for anatomical leg length and in 46 out of 105 subjects an analysis of pelvic rotation ranged from 0-3.0° with a mean of 0.9°.

Plaugher et al.\textsuperscript{45} studied the reliability of patient positioning utilizing anterior-posterior pelvic radiography. There were 20 volunteers that had repeat radiography after approximately 1 hour and 17 subjects who received follow-up radiography after 18 days. The authors chose Gonstead technique line drawing procedures for analysis of the pelvis and leg length discrepancies. In the first group, the results showed there were no statistically significant differences (p > .05) between the two radiographs at one hour apart. The second group showed similar results at an average of 18 days (p > .05).
**Diagnostic Capabilities**

Juhl et al.\(^2\) found a low correlation between femur head un-levelness (FHU) and sacral base un-levelness (SBU). Therefore, pelvic obliquity, which measures the amount of lateral bending or z-axis rotation created in the pelvis, may be method of choice on the AP Fergusson radiograph. Leveling the sacral base makes better sense than leveling the femur heads because the pelvis is not always symmetrical and the goal in musculoskeletal treatment is to remove imbalance to lessen the stresses of gravity on the body.\(^{46-49}\)

The AP Ferguson gives the doctor the clearest view of the lumbo-sacral junction with the least amount of distortion and asymmetrical magnification allowing for a more accurate measurement of the sacral base levelness. This view is accepted for the assessment of the sacral iliac joints, transitional vertebra, lumbo-sacral disc degeneration and for other anomaly detection.

**Validity**

An estimated 90% of the population has a LLI of 5mm or more.\(^{35}\) Importantly, the prevalence and size of the LLI is significantly greater in pain groups versus symptomatic subjects.\(^{23,24,39,44}\) Studies have found that LLI correlates to lower back pain (LBP) and radiographic evaluation has been shown to be the most accurate method to evaluate it.\(^ {5-20}\)

Oddly, regarding validity of LLI assessment, the recent CCGPP “Best Practices” Guidelines stated, on page 78: “Finally, the procedure [radiographic measurements] has not been studied as to its validity, making the use of this as an outcome questionable (59).”\(^{51}\)

Interestingly, their\(^{51}\) reference #59 is a 1985 literature review by Lawrence. In direct opposition to this CCGPP statement,\(^ {51}\) recent and past validity investigations on assessment of LLI and sacral unleveling have found that radiographic evaluation is the most accurate and valid.\(^ {2,5,7,9-11,16,37,40,41}\) Apparently, the CCGPP committee\(^ {51}\) did not investigate this topic thoroughly.

LLI shows a correlation to unleveled sacral bases although the relationship is not directly proportional.\(^ {2,13,19}\) For example, in the study by Juhl et al.\(^2\), of 421 patients with LBP, most were found to have LLI (leg length inequality) and sacral unleveling on the same side. However the LLI and sacral unleveling were not always proportional; Juhl discussed the importance of measuring sacral base unleveling (SBU) and not just femoral head unleveling (FHU).

Summarily, the alignment of the AP Ferguson-pelvic Radiographic view as been found to correlate to and have predictive validity for the following conditions:

1. low back pain,\(^{22-24,39,44,52}\)
2. sacral base unleveling correlates to the side of LLI,\(^ {2,13,19}\)
3. lumbo-sacral facet joint arthritis,\(^ {33,34}\)
4. lower-leg stress fractures,\(^ {33,34}\)
5. various chronic musculoskeletal pains,\(^ {48,49}\)
6. some visceral disorders.\(^ {48,49}\)

In contrast to the above validity information, two investigations have questioned the AP Fergusson/pelvic views validity.\(^ {50,53}\) For example, one investigation has found that the sacral tilt to horizontal in the coronal plane on the AP Pelvic radiograph does not correlate to lower back pain.\(^ {50}\) However, this report, did not assess their control group without lower back pain using
standardized questionnaires of any type. Furthermore, the authors go on to state that they still use lift therapy to level the sacral tilt (pelvic obliquity) in their clinic for patients with chronic low back pain and that this seems to be effective. Secondly, Robbins et al,\textsuperscript{53} reported on one hundred consecutive patients in whom radiographs of the sacroiliac joints (similar to the AP Fergusson view) had been requested concurrently with radiographs of the lumbar spine and/or pelvis. They concluded that “\textit{In no case did the sacroiliac joint radiograph result in a normal diagnosis being changed to abnormal.}” However, Robbins et al,\textsuperscript{53} did not look at LLI and sacral unleveling. The astute clinician may replace the standard AP Lumbar with a “modified AP Fergusson” tilt up x-ray view to avoid repeated views if desired.

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the AP Fergusson-pelvic radiographic alignment and the conditions in the above 6 categories is superior to the few negative correlation studies. Thus, we conclude that the AP Ferguson-pelvic radiographic alignment has positive correlation and predictive validity for these 6 categories.\textsuperscript{2,13,19,22-24,33,34,39,44,48,49,52,54}

**Outcome Studies Leveling the Sacral Base**

Correction of LLI and sacral unleveling with shoe orthotics has shown symptomatic improvement in several chronic pain populations.\textsuperscript{10,21-32,39,47-49,52,54} Prevention of future lumbar degeneration and stress fractures has also been suggested as benefit of reduction of LLI.\textsuperscript{33,34} Furthermore, a high compliance has been shown with the use of heel lifts.\textsuperscript{28}

**Level I Studies:**

In a recent randomized trial, Defrin et al\textsuperscript{22} found statistically significant improvements in chronic low back pain in patients receiving shoe lifts compared to no treatment in the control subjects. In both the control and lift treatment groups, the measured LLI was less than 10mm as measured via radiograph.

**Level II Studies:** No level II studies could be located.

**Level III Studies:** No Level III studies could be located.

**Level IV Studies:**

Some authors have suggested that the right triangle method to level the sacral base might be a better method for clinical significance patient outcomes. In 2 separate investigations by Irvin\textsuperscript{48,49}, chronic musculoskeletal pains were alleviated by leveling the sacral base on the AP Ferguson radiograph. Of interest, several visceral conditions were found to be improved as well. Dulhunty\textsuperscript{54} reported on the successful management of 3 patients with various musculoskeletal complaints, including back pain and restricted ranges of movement. A multi-modal treatment approach was utilized including shoe lift therapy to reduce the amount of pelvic-sacral obliquity as measured via x-ray.
Conclusion

Because there is such a high incidence of LBP in the general population (85% in some studies) and there appears to be a high correlation of LBP to LLI and SBU\(^2\), the AP Ferguson view should be a part of the routine x-ray series performed on all patients with a symptomatic history of spinal pain, leg pain, hip pain, knee pain or abnormal postures evident on physical evaluation. The available data support the use of corrective orthotics to reduce radiographically identified LLI and SBU. Clinical judgment in combination with this literature should aid in the reduction of subluxation/biomechanical alterations in both symptomatic and asymptomatic populations of patients presenting to chiropractic clinicians.
References


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16. AP Femur Head Radiographic View

RECOMMENDATION

The AP Femur Head Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention; response to care can then be determined.


PCCRP Evidence Grade: Clinical Studies = B, C, D and Reliability, Population, Biomechanics and Validity studies = a

Introduction

The assessment of the patient with observed gross postural distortion is incomplete without the analysis of a weight bearing radiographic view of the pelvis and lumbar spine, including the femur heads. When thoraco-lumbar-pelvic postural asymmetry exists, further investigation of the patient’s structure is needed to accurately assess the root source of the asymmetry. The AP femur head projection is a valuable tool for the chiropractic clinician to evaluate a patient’s structural abnormalities and many chiropractic techniques utilize assessment of leg length to determine their clinical approach to the patient. Radiographic information is the gold standard for determining lower limb inequality.1-10

The AP Femur Head Projection (APFH) is exposed at 40” focal film distance. The projection is exposed with the patient standing with weight even on both feet, with the pelvis centered with the center of the bucky or film holder in such a way as to align the pubic symphysis with the second sacral tubercle. The patient’s feet are in a neutral anatomical position and are positioned femur head width apart. The patient is in bare feet and is instructed to relax in a natural stance. The patient’s bilateral gluteal musculature will be lightly touching the bucky or film holder. In the horizontal dimension, the central ray will be positioned as close to the femur head height as possible. See Figure 1.

The APFH is utilized primarily to determine the measurable discrepancy in a patient’s leg length, to confirm or refute the existence of a structural limb length discrepancy. The AP Femur Head Radiographic Projection is not usually a stand-alone radiograph. It is most effectively utilized as an additional assessment of the AP Ferguson and along side a standard weight bearing Anterior- Posterior Lumbo-Pelvic view. This is due to the fact that some patients can have anomalies of the sacrum/pelvis that correct for the leg length inequality.2

Reliability of Line Drawing Analysis

Classically, using the APH x-ray view, a line is constructed consisting of two points, the highest point of the top of each femur head. A line is then constructed level with and parallel to the floor and at the level of the most cephalad femur head and another short line is constructed parallel with the floor or the more caudal femur head (relative to the other femur head of course). The difference between the two femur head heights is measured and recorded. See Figure 2.
A review of the literature finds that radiographic evaluation is reliable compared to unreliable clinical (palpation of landmarks). A multitude of studies have identified excellent inter and intra examiner reliability of leg length inequality with a standard error of measurement of 1-3mm for radiographic assessment of left versus right leg length measures.\textsuperscript{11-26}

\textbf{Figure 1.} The AP Femur Head Radiographic (APFHR) view is taken at 40 inches with the central ray at the height of the femur heads and parallel with the leveled floor. The patient’s feet are femur width apart, the pelvis is centered relative to the film and central ray, and any gross postural abnormalities should be removed to identify the true short leg anomaly.

\textbf{Figure 2.} Measurement of leg length inequality on the AP Femur Head Radiographic View. Line A is across the superior aspects of the iliac crest. Line B is drawn across the sacral base. Line C is drawn across the superior aspect of each femoral head. A horizontal line (not labeled) is drawn across using the height of the superior femur head. The Distance D is the leg length inequality and is the vertical distance from the superior aspect of the ‘short’ femur to the horizontal line. Some authors only consider the Distance D to be significant if it matches the tilt of line segments A and B and the side of lumbar spine curve convexity.
Reliability of Patient Positioning Procedures

At least 7 separate studies have been performed on repeated AP pelvic radiographs on the same subjects with both an intra and inter day and multiple examiner methods. Without exception, excellent reliability has been found for repeated measures on repeat radiographs for LLI. Using repeated radiographic views of the same subject, Giles and Taylor\(^{13}\) and Clark\(^{14}\) found a standard error of repeatability of femur head measures of 1-3 mm. In both studies, there was intra and inter-rater reliability and x-rays were taken by different radiographic technicians. Similarly, Beal\(^{12}\) and Friberg et al\(^{15}\) found repeatability of femur height of 1-2mm in repeated radiographs taken from 1-30 months after the patients’ initial radiographic examination. Leppilahti et al\(^{16}\) examined the radiographs of 15 subjects taken at 2 separate intervals on the same day. A mean error of repeated measures for femur head differences were 1.0mm, with a range of 0-2mm and a correlation coefficient of 0.96.

In 105 patients with chronic low back pain, Friberg\(^{27}\) retook pelvic radiographs in order to analyze the consistency of anatomical leg length inequality and pelvic rotation about the gravity axis. Radiographs were repeated after an interval of 2 weeks to 3 years. The mean error between repeat x-rays was 0.7 mm for anatomical leg length and in 46 out of 105 subjects an analysis of pelvic rotation ranged from 0-3.0\(^{\circ}\) with a mean of 0.9\(^{\circ}\). Plaugher et al\(^{28}\) studied the reliability of patient positioning utilizing anterior-posterior pelvic radiography. There were 20 volunteers that had repeat radiography after approximately 1 hour and 17 subjects who received follow-up radiography after 18 days. The authors chose Gonstead technique line drawing procedures for analysis of the pelvis and leg length discrepancies. In the first group the results showed there were no statistically significant differences (p > .05) between the two radiographs at one hour apart. The second group showed similar results at an average of 18 days (p > .05).

Validity

Multiple studies have compared the means, standard deviations and frequency distributions of femoral head inequality in control subjects versus various pain groups. Concerning chronic low back pain populations, the data indicates that there is a statistically significant larger mean value of inequality and greater frequency of occurrence for a difference as small as 4mm but much stronger data for differences of 10mm or greater.\(^{11,13,24,27,29}\) Other authors have found a statistically significant relationship between the side of leg length inequality and side of lower back pain.\(^{55}\)

Some authors have questioned the validity of the APFH radiographic view. For example, the recent CCGPP “Best Practices” Guidelines stated, on page 78: “Finally, the procedure [radiographic measurements] has not been studied as to its validity, making the use of this as an outcome questionable (59).”\(^{56}\) Interestingly, their reference #59 is a 1985 literature review by Lawrence.\(^{10}\) In direct opposition to this CCGPP statement,\(^{56}\) recent and past validity investigations on assessment of leg length inequality (LLI) and/or sacral unleveling on the APFH view have found that radiographic evaluation is the most accurate and valid.\(^{2-9,14,15,18,21,37}\) Apparently, the CCGPP committee\(^{56}\) did not investigate this topic thoroughly or has decided to ignore the available evidence.

Significantly, the alignment of the AP Femur/pelvic Radiographic view as been found to correlate to and have predictive validity for the following conditions:

1. low back pain,\(^{11,13,24,27,29,30,55}\)
2. knee injuries,\(^{17,31-33}\)
3. lumbo-sacral facet joint arthritis,\(^{34,35}\)
Oppositely, a few investigations have found that the AP Femur head alignment measurements do not correlate to and predict the findings in the above 6 categories. However, part of this may be due to the lack of consideration of the pelvis, sacral base alignment, and lumbar alignment in some of these populations.

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the APFH Radiographic alignment and the conditions in the above 6 categories is superior to the negative correlation studies. Thus, we conclude that the APFH Radiographic view has positive correlation and predictive validity for the above 6 categories.

### Outcome Studies

The use of heel and heel and sole lifts is common practice in many structural approaches to patient care and management. By establishing a baseline analysis with the patient exhibiting asymmetrical leg length, repeat projections exposed with the addition of a heel or heel and sole lift can be exposed and analyzed to determine the effect of an orthotic or lift on lumbar and pelvic weight bearing and leg length equality. Many clinicians will immediately expose an additional radiograph with the same parameters as the original to determine the effect on the patient’s structure. Other clinicians advocate a gradual “build-up” of the lift to allow the soft tissues time to accommodate the change in femur head height.

Multiple investigations have been performed using shoe lifts to level leg length inequality in a variety of pain populations and in patients with spinal deformities. These studies suggest that lift therapy determined by radiography has positive correlation to patient pain and disability improvements. The majority of these investigations are Level III and Level IV studies.

#### Level I Studies:

For example, in a randomized trial, Defrin et al found statistically significant improvements in chronic low back pain in patients receiving shoe lifts compared to no treatment in the control subjects. In both the control and lift treatment groups, the measured LLI was less than 10mm as measured via radiograph.

#### Level II Studies: No Level II studies could be located.
References


E. Full Spine Views

17. AP Full Spine Radiographic View

RECOMMENDATION

The AP Full Spine Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Validity, Biomechanics = a.

Introduction

As referenced by Rowe, in 1932 a chiropractor named Sausser took the first 14” x 36” AP Full Spine x-ray. Many chiropractic techniques utilize this radiographic view, including Gonstead, Toftness, Logan Basic, Meric, and Diversified (Figure 1). Additionally, it is the view of choice for a determination of scoliosis. In his classic 1985 text, Hildebrandt suggested that there are five projections that comprise a complete full spine analysis, one of which is the AP Full Spine view:

1. AP full spine,
2. Lateral full spine,
3. Femoral head view,
4. Sacral base view,
5. Upper cervical view.

The AP full spine view requires a 14in X 36in screen and grid cabinet. This view is taken with a tube-grid distance at 72in and can be taken at 84 in. One tries to have the occiput and femur heads all visualized on the 14 X 36 in film. It is often obtained in 2-3 takes with split screens. Proper positioning for this view can be found in a text chapter by Rowe and Yochum and Rowe (pp. 44).

Reliability of Line Drawing Methodology

In chiropractic, the wedge angle method is the most common radiographic analysis on AP Full Spine radiographs. In 1991, Plaugher and Hendricks performed a pelvic mensuration reliability study on 71 AP full spine radiographs with two examiners marking each film twice. High reliability was ascertained with the Pearson r, Spearman, intra-class correlation coefficient (ANOVA) and Kappa statistics. All results were statistically significant (P < 0.001) and indicated high levels of concordance.
Additionally, the Gonstead technique utilizes the end plate line analysis that is inherent with in the Cobb angle method.\textsuperscript{4,10-15} The Cobb method have been shown to have high reliability.\textsuperscript{10-13}

For example, Shae et al\textsuperscript{10} reported on a reliability study where 24 AP full spine scoliosis radiographs were measured by six examiners. Two measurement sets were done manually ("manual set"), and two measurement sets were done on digitized images using a computer mouse ("computer set"). For the manual set, the 95\% confidence interval for intraobserver variability was 3.3 degrees (range, 2.5-4.5 degrees). For the computer set, the value was 2.6 degrees (range, 2.3-3.3 degrees). This difference in 95\% confidence intervals between the manual and computer sets was statistically significant (P < 0.001). Their\textsuperscript{10} results demonstrate that intraobserver variability for manual and computer Cobb angle measurements yield a 95\% confidence interval of approximately 3 degrees, with the computer having a slightly lower variability.

In 1990, Carman et al\textsuperscript{12} stated that for measurements of scoliosis on AP full spine views, “the average difference between readings was 3.8 degrees, and 95 per cent of the differences...
were 8 degrees or less (range, 0 to 10 degrees). These findings were in keeping with those of other published reports.”

For another example, Morrissy et al\(^\text{13}\) reported on the intrinsic error in measurement for 50 AP full spine radiographs of patients who had scoliosis. AP full spine films were each measured on six separate occasions by four orthopaedic surgeons using the Cobb method. “For the first two measurements (Set I), each observer selected the end-vertebrae of the curve; for the next two measurements (Set II), the end-vertebrae were pre-selected and constant. The last two measurements (Set III) were obtained in the same manner as Set II, except that each examiner used the same protractor rather than the one that he carried with him. The pooled results of all four observers suggested that the 95 per cent confidence limit for intra-observer variability was 4.9 degrees for Set I, 3.8 degrees for Set II, and 2.8 degrees for Set III. The inter-observer variability was 7.2 degrees for Set I and 6.3 degrees for Sets II and III. The mean angles differed significantly between observers, but the difference was smaller when the observers used the same protractor.”

Besides the Cobb method of Scoliosis analysis, the Risser-Ferguson method is also popular.\(^\text{4,14,15}\)

Reliability of Patient Positioning

If the subject is positioned with the heels squared to the grid cabinet, there has been some criticism of the AP full spine view whenever the subject has pelvic axial rotation compared to the feet.\(^\text{16}\) In such a case, the pelvis and whole spine is in a slight oblique position to the central ray. This criticism can be largely overcome by centering the pelvis to the central ray and positioning the subject using a neutral resting posture.\(^\text{17}\)

Several investigations have been performed on the test re-test reliability of patient positioning for the AP/PA full spine or sectional AP thoracic measurements.\(^\text{18,19-24}\)

Problematically, many authors have misrepresented the scientific evidence on this topic and offer their Class V opinion that radiographic positioning is a significant source of error for AP/PA thoracic spine measurements.\(^\text{20,21}\) For example, Capasso\(^\text{20}\) claimed that difference in the curve of up to 17° can occur between an AP standing radiograph compared to a that obtained with a positioning device. A review of pertinent studies provides a different conclusion.

In 1978, Dawson et al\(^\text{22}\) took repeated AP full spine x-rays on 60 scoliosis patients in the upright and the scoliosis chariot (SC) positioning device on the same day. Fourteen subjects had 2 scoliosis chariot x-rays exposed within 5 minutes of each other (3 total x-rays in each of these 14 subjects). Average differences in Cobb angle between the AP full spine and SC view were 3.4°-7.5° (increasing as curve magnitude increased). The difference in 2 repeated SC views were all within ± 3°. The authors concluded that SC views for scoliosis were more repeatable.\(^\text{22}\)

However, repeated AP full spine views were not performed on the same subject. Therefore, this study shows that as long as the clinician uses the same positioning procedures, then high examiner reliability will be found. This study\(^\text{22}\) was misinterpreted by Capasso.\(^\text{20}\)

In 1982, Desmet et al\(^\text{23}\) took AP and PA full spine x-ray views of 78 scoliosis patients with an average time of 5-15 minutes between radiographs. Strong correlation between curve measures on AP vs. PA full spine films was found; \(r = .960\). The PA view demonstrated a mean increased curve of 1.71° compared to the AP view. In 5/128 curves a 9°-13° increase, in 19/128 curves a 6°-8° increase, and in 4/128 curves a 6°-8° decrease on the PA film was found. The difference in curve values is due to projection of endplates on PA vs. AP films. However, this
study does not indicate that positioning is a source of error as long as the same procedures are followed.

In 1995, Kohlmaier et al. 24 took 2 AP full spine x-rays (standing and in a positioning device) of 100 scoliosis subjects. They concluded that the balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards. However, Kohlmaier et al. 24 did not actually investigate the repeatability of the same position on each subject therefore no conclusions can be drawn.

In order to investigate positioning errors, Sevastikoglou and Bergquist 19 took 17 frontal plane radiographs of 2 scoliosis skeletons: neutral, rotation up to 10° left/right and 5 cm elevation or depression of the tube height. Two examiners assessed the curves using the Cobb and Riser-Ferguson methods. They found little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson’s method and 2.06° ± 1.09° for Cobb’s method. This information 19 was misinterpreted and inaccurately reported by Capasso et al. 20

Pruijs, et al., 18 investigated the repeatability and reliability of thoracic, thoracolumbar and lumbar Cobb angle measurements by studying two sources of error: the production of the radiograph and drawing/measuring the lines/angles. Regarding the production of the radiographs, the investigators compared serial radiographs in patients who underwent surgical spinal fusion for scoliosis and therefore had a fixed spinal curve. They discovered that the production of the series of radiographs produced a standard deviation in the Cobb angle of only 3.2°. This is often less than the standard error of measurement, as discussed previously in some studies. In other words, the measurement method may not be sensitive enough to detect any ‘true’ differences in the curve caused by positioning.

Based on the above review, it is the consensus of the PCCRP panel that positioning procedures for exposing the AP Full Spine radiograph is reliable as long as the same procedures are followed on initial and repeat films. We recommend that the pelvis be centered relative to the bucky in order for less distortion and a more accurate analysis.

Diagnostic Capabilities

When properly performed, the AP full spine radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The occiput down to the femur heads and pubic symphysis should be visualized. The AP full spine radiographic view provides the chiropractic clinician with valuable information including:

• Ability to diagnose scoliosis and for measuring with Cobb angles,
• Balance of all the spinal regions (cervical, thoracic, and lumbar) alignment and posture,
• Ability to account for total alignment changes caused by fractures, hemi-vertebrae, short leg discrepancy, laterolisthesis, and many other pathologies and anomalies.
• Lastly, this view provides the means to accurately count the number and respective levels of vertebrae.

Validity of the AP Full Spine View

There are several issues to consider when addressing the validity of the AP Full Spine radiographic view. First is the radiation exposure level that a patient would experience. According to Rowe, “An AP full spine view using a 400 film screen speed combination yields
about 145 mrem of total body exposure.” And “This would mean that a 30-year-old man would have to receive a minimum of 333 AP full spine exposures at 400 speed before the National Academy of Science guidelines would be met. A 1200 speed system with gonadal shielding would require more than 1000 AP full spine exposures to double the risk of the genetic mutation rate.”

This is using an annual dose limit of 10 Rem (See Section VII as well).

Cracknell and Bull investigated and quantified the difference in both full-body effective doses and absorbed doses resulting from 3 AP sectional spinal x-rays (AP cervical, thoracic, and lumbo-pelvic) compared to the AP Full Spine radiograph. Using Lithium fluoride (LiF) thermoluminescent dosimeters (TLD-100) placed on an accurate anthropomorphic phantom, doses were calculated. When compared with AP sectional exposures, the AP full-spine exposure gave consistently less absorbed doses to all critical organs.

Kuklo reported on 112 patients assessed and treated for proximal thoracic scoliosis and resultant shoulder imbalance. The AP Full Spine radiograph was used. The clavicular height was the only radiographic variable measured that was predictive for accuracy of shoulder height (measured as the soft tissue shadow on the film) in subjects treated surgically for scoliosis in three out of the four groups studied (P = .0009, .0193, .0716 and .0007).

Outcome Investigations

Although many chiropractic techniques and clinicians utilize the AP full spine radiographic view, only Level IV studies could be located on this view in chiropractic treatment outcome studies.

Collectively, however, the data presented in the previous sections suggest that utilization of a multi-modal treatment approach, including chiropractic techniques, would show positive change on the AP Full spine radiographic view and that this might have the ability to improve a patients health, pain, and disability levels. These types of investigations need to be performed by practicing chiropractors and/or researcher investigators.

Level I Studies: No studies could be located.

Level II Studies: No studies could be located.

Level III Studies: No studies could be located.

Level IV Studies:

In 1977, the late I.N. Toftness self published his text with results from 100 cases utilizing AP full spine radiographs.

In 1991, Plaugher et al authored a Gonstead text book with multiple cases studies utilizing the AP full spine view.

In 1993, Haney reported on a juvenile migraine head ache case with resolution of symptoms and pre-post AP full spine radiographic improvements.

In 1994, Araghi reported on improvements in a 5 year old with oral apraxia, with concomitant improvements in alignment of pre-post AP full spine radiographs.

In 1996, Eriksen reported on a scoliosis correction with upper cervical chiropractic care with a nasium pre-post and with an AP full spine pre-post reduction in the Cobb angle in both the thoracic and lumbar regions.

In 2001, Golembiewski and Catanzaro reported on a Case Study of a 28-year-old female, whose...
scoliosis was reduced, using Cobb angle analysis, with ASBE procedures. The patient repeated the
ASBE cross-over exercises daily for 5 months. In 2004, Gilmour et al\textsuperscript{32} reported on AP full spine scoliosis correction utilizing the
Pettibon weighting system.

In 2004, Morningstar et al\textsuperscript{33} reported on 19 scoliosis patients. Antero-posterior radiographs were
taken of each subject prior to treatment intervention and 4-6 weeks following the intervention. After 4-6
weeks of treatment, the treatment group averaged a 17 degrees reduction in their Cobb angle
measurements. None of the patients' Cobb angles increased.\textsuperscript{33}
In 2006, Morningstar and Joy\textsuperscript{34} reported on 3 atypical cases of scoliosis. Each patient was
treated with a novel active rehabilitation program for varying lengths of time, including spinal
manipulation and a patented external head and body weighting system. Following a course of
treatment, consisting of clinic and home care treatments, post-treatment radiographs and examinations
were conducted. Improvement in symptoms and daily function was obtained in all 3 cases.
Concerning Cobb angle measurements, there was a reduction in Cobb angle of 13 degrees, 8 degrees,
and 16 degrees, respectively, over 12 weeks of treatment.\textsuperscript{34}
In 2007, four cases of scoliosis were treated with bracing, a patented weighting system,
vibration therapy, and manual traction procedures.\textsuperscript{35} The evaluation process consisted of multiple
outcomes, including radiographic, functional, respiratory, and postural assessments. Patients were
evaluated at the onset of treatment and after 90 days. All 4 patients saw their major curvatures
reduced an average of 13.5\textdegree. Peak expiratory flow, computerized postural assessment, chest
expansion, rib hump measurements, and functional rating index scores also improved for all
patients.\textsuperscript{35}
References


18. Lateral Full Spine Radiographic View

RECOMMENDATION

The Lateral Full Spine Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics, and Validity = a.

Introduction

In radiography of the spine, the full spine radiographic view is an accepted norm. According to the Scoliosis Research Society, “…complete discussion of sagittal balance clearly needs to address both the axial skeleton and lower extremities, including the hips. Measurement of sagittal contours needs to be distinctly documented for useful comparison. The standing 3’ radiograph with appropriate grids at a focal distance of 72’’ is clearly the accepted norm.”

Care should be taken to insure that several structures are visible from at least the lower half of the skull superiorly to the pelvis and both femur heads inferiorly. For proper penetration and visualization, in almost all cases, a lateral cervico-thoracic filter and a lateral lower lung field filter (T7-T12) are needed in order to adequately visualize the entire spine.

In chiropractic analysis, the lateral full spine radiographic (LFSR) view should be taken in the upright standing position at the standard tube distance of 180 cm (72 inches) with the central ray located approximately at the T6-T7 disc level. Most commonly in today’s practice, the LFSR is taken in one exposure on a 14 inch x 36 inch cassette and film; however it can be taken in two exposures. For the LFSR view, the patient’s arms must be positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height, by holding arms out almost 90° in front grasping a stand, or by folding the arms on the chest and placing the hands in the clavicular fossae.

Since chiropractic clinicians are interested in the alignment of the patient’s individual spine, the self balance position is most appropriate to ascertain the patient’s unique subluxation alignment. The patient’s abnormal sagittal plane posture should be left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the ‘self balance positioning’ for the LFSR.

Reliability of Measurement Methods

The LFSR view measurements include the total curve measurements at a various cervical, thoracic, lumbar, and pelvic levels, sagittal balance (flexion/extension and sagittal translation) of the upper versus lower regional (cervical, thoracic, lumbar) levels, segmental vertebral curvature values from S1-C1, total sagittal balance with the C7-S1 and C1-S1 plumblines, and pelvic morphology measurements. See Figures 2 and 3. These methods have been analyzed in a multitude of different ways on lateral full spine radiographs.
In a repeated measures design, Rillardon et al used 100 films and 5 examiners to compare manual measurements and computerized measurements on the LFSR views. Intra-class ICCs varied from 0.82 to 0.96 and inter- and intra-observer variabilities were comparable for the measurement techniques for thoracic kyphosis, lumbar lordosis, pelvic index, pelvic tilt, and slope of the sacrum. Significantly, inter- and intra-observer variability was smaller when the sagittal tilt was measured with the computer.

In another LFSR view reliability study, Rajnics et al investigated the inter and intra-examiner reliability of several variables. Excellent reliability with small standard errors of measures were found (< ±1.5°) when the operator was designated as experienced. Less (±-6.5º) repeatable measurements were found for T4-T12 kyphosis due to poor contrast on radiographs of the upper thoracic vertebrae.

Collectively these studies indicate that measurement of the lateral lumbo-pelvic radiographic alignment has excellent observer reliability for a variety of methodology.

**Repeatability of Patient Positioning**

Several investigations have been performed in an attempt to identify the optimal, repeatable LFSR view patient position. These investigations clearly demonstrate that the LFSR alignment on follow-up radiographs is repeatable if standardized procedures are followed. There is a difference in sagittal balance with the ‘functional’ radiographic positioning procedures that place the arms too far out in front of the body’s center of gravity. However, the lordosis and kyphosis stay relatively constant.

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**Figure 1 A-D.** Self balance position for the lateral thoracic radiograph. In A, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In B, the patients arms are flexed nearly 90 at the shoulder and the hands are placed on a pole. In C, the patient assumes the ‘self balance position’ and then the arms are folded on the chest placing the hands in the claviular fossae.
Figure 2A-D. In A, the cervical sagittal balance line is shown. In B, the thoraco-pelvic sagittal balance line is shown. In C, the regional thoracic balance plumbline is shown. In D, these lines are drawn on the full spine lateral view in order to determine full spine regional sagittal alignment.

Figure 3. Lateral full spine sagittal balance and modeling measurements. In A, the C7-plumbline is shown. The centroid of C7 vertebral body is used to drop a vertical line inferiorly. The distance from this line is compared to the posterior superior body corner of S1. In B, the S1 plumbline is shown. A vertical line is drawn vertically upward from the posterior inferior body corner of S1. The horizontal distance of the posterior inferior body of T1 and posterior superior lateral mass of C1 is compared to this line. In C, the regional sagittal balance of the lumbar, thoracic, and cervical spines are shown on the full spine lateral using angular displacements from vertical of the upper versus lower spinal section.
In general, this literature survey evidences that the positioning procedures for the hands at iliac crest height, with the shoulder flexed around 30°, elbows slightly bent and the arms folded on the chest with the hands in the clavicular fossae are the two most appropriate positioning for the LFSR view. See Figure 1A and 1C.

Diagnostic Capabilities

When properly performed, the lateral full spine radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, spinous processes, sacrum, and femur heads should all be visualized. The lateral full spine radiographic view provides the chiropractic clinician with valuable information including:

- a global view of the sagittal balance of C1, T1, T12, and S1,
- an evaluation of forward/backward head translation,
- an evaluation of forward/backward ribcage posture,
- an evaluation of sagittal posture (from the postural examination) and spinal coupling on the radiograph,
- an evaluation of cervical lordosis,
- an evaluation of thoracic kyphosis,
- an evaluation of lumbar lordosis,
- an evaluation of pelvic tilt,
- an evaluation of pelvic morphology,
- an evaluation of any retro- or spondylo-listhesis and,
- an evaluation of spinal degeneration (vertebrae, discs, spinal ligaments),
- spinal canal dimensions, and
- ability to accurately count the number and respective levels of vertebrae,
- a number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed and found correlation and predictive validity of the lateral full spine radiographic alignment to a variety of health related conditions including:

1. back pain,3,23
2. full spine sagittal relationships to clearly identify hyper/hypo cervical lordosis, hyper/hypokyphosis, and hyper/hypolordosis,1,5,6,10,15,21-24
3. stress/strain relationships & degenerative joint disease (DJD),6,22,25,26
4. physical disability & functional impairments,27,28
5. risk of ageing deformity progression and vertebral body fractures,29,30

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the lateral full spine radiographic alignment and the conditions in the above categories is of adequate quality. Thus, we conclude that the lateral full spine radiographic alignment has positive correlation and predictive validity for these categories.1,5,6,10,15,21-30
Outcome Investigations

Although many chiropractic techniques and clinicians utilize the lateral full spine radiographic view, only Level IV studies could be located on this view in chiropractic treatment outcome studies.\textsuperscript{33,34} Collectively, however, the data presented in the previous sections suggest that utilization of a multi-modal treatment approach, including chiropractic techniques, would show positive change on the LFSR view and that this might have the ability to improve a patient's health, pain, and disability levels. These types of investigations need to be performed by practicing chiropractors and/or researcher investigators.

Level I Studies: No Level I studies could be located.

Level II Studies: No Level II studies could be located.

Level III Studies: No Level III studies could be located.

Level IV Studies:
Numerous case reports showing corrections of the biomechanical component of vertebral subluxations using the Full Spine Lateral radiograph were presented by Plaugher\textsuperscript{33} and Toftness.\textsuperscript{34}
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19. **Bending and/or stress films for the assessment of scoliosis or buckling**

**RECOMMENDATION**

The Bending and/or Stress Radiographic views are indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view should be obtained when significant scoliosis, buckling, or other unusual spinal configurations are present that do not match typical postural presentations in the AP view. These radiographic views have reliability, biomechanics, validity and clinical outcomes data that evidence their clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

**Supporting Evidence:** Reliability studies class 1 and 2, Biomechanics, Population Class 2 studies, and Validity.

**PCCRP Evidence Grade:** Clinical Studies = C, D and Reliability, Biomechanics, and Validity = a.

**Introduction**

Stress films are commonly taken in the assessment of scoliosis flexibility. Surgeons take stress views to assess the flexibility of an idiopathic scoliotic curve prior to surgery to get an estimate of the amount of correction that can be achieved and to determine levels of fusion/instrumentation placement. Curve flexibility has been investigated for quite some time. It has been commonly accepted that the more flexible a curve, the higher the risk of progression if left alone, but the easier to change with non-operative treatment. There are currently several methods orthopedists and radiologists use to objectively detect the degree of flexibility of a structural curve.

One method commonly used is to take a full spine radiograph with the patient stressed into lateral flexion while in the prone position. This has also been reported in the standing, and supine positions. The average correction obtained in a pure lateral bending stress film appears to be between 35-88%. Variation may exist due to reporting on different curve patterns, age of subjects, etiology of the scoliosis and the technique used to obtain the stress film. Another variation of the lateral bending method has been reported. Cheung placed patients in a side-lying position with the apex of the curve over round fulcrum; alternatively a 2-3 inch wide strap can be used to pull down at the apex of the curve. (See Figure 1) These side-lying, fulcrum-bending films have primarily been shown good results for reducing thoracic curves. This was confirmed by Luk, et al in 1998 and Klepps et al in 2001.

The last method found in the literature is the prone push film. This method utilizes lateral translation (shear) forces applied by a technician while the film is taken with the patient lying prone. Both studies reported a 42% correction of the Cobb angle. Vendatam, et al conclude, “the current study of the prone push radiograph showed that it is superior to the lateral-bending radiograph in predicting the postoperative translation and rotation of the lowest instrumented vertebrae”. They note that the two methods investigated were similar in predicting Cobb angle improvement.
It is difficult to determine which, if any, technique is most effective, since most of these studies do not compare different methods within the same group of subjects. Factors, such as curve pattern, magnitude and sagittal alignment will most certainly affect vertebral coupling patterns in a different manner in response to the same main motion. With this in mind, different curves will respond to two or more main motion postural combinations in accordance with the biomechanical principle called the non-commutative property of finite rotation angles upon addition. This has been discussed in the literature and form the basis for scoliosis stress films described by Harrison.\textsuperscript{13}

Some studies have described axial traction radiographic views. White and Panjabi\textsuperscript{14} reasoned that axial distraction loading would only be appropriate in scoliosis curves exceeding $53^\circ$, while curves under $53^\circ$ would respond better to transverse loads. Takahashi, et al\textsuperscript{15} showed that, “In thoracic curves, the postoperative Cobb angle was highly correlated with the preoperative Cobb angle in traction ($r = 0.82$). However, such correlation was much lower with lumbar curves ($r = 0.54$). The reducibility of the thoracic curve by traction as expressed by the ratio to the original curve was dependent on the magnitude of the original curve ($P = 0.005$)”.\textsuperscript{15}

Polly and Sturm\textsuperscript{16}(1998) demonstrated similar results comparing halo-femoral traction (longitudinal distraction) to supine side bending in a clinical study for curves above and below $60^\circ$. In 1982, Kliemen, et al,\textsuperscript{11} found conflicting results. They performed a study on 58 subjects using the prone push radiographs (transverse loads) to estimate postoperative correction. They

\textbf{Figure 1A-C}: Side lying scoliosis fulcrum-bending stress film. In A, the patient’s standing pre-operative AP lumbar radiograph is shown. In B, the patient is positioned in left thoracic translation and right thoracic lateral flexion with movement emphasized to the thoraco-lumbar spine and an x-ray is taken. In C, the reduction of the curve on the stress film is shown. Reprinted with permission: Harrison CBP Seminars, Inc. 2005-2006.
found that for curves less than 50° (N=42 curves), an average of 18.9° of correction was achieved as compared to an average of 23.4° correction of curvatures over 50° (N=40 curves). They did not study the effect of axial traction forces. Average values of magnitude for the two groups of curves were not reported, nor were the percent correction of the two groups. From a non-operative, conservative clinical point of view, these findings are important to understand.

For all curves under 50-60°, intervention using axial traction will be less likely to effectively manage the curvature. Transverse loading and fulcrum bending are more appropriate. Since most patients seeking non-operative intervention have curvatures that fall into this range, this is where our focus lies. For magnitudes over 50-60° applications of axial distraction forces, also referred to “extension” by some authors, may facilitate greater correction, even though transverse shear forces and fulcrum bending will still reduce the curve. It is also important to note that flexibility dramatically decreases as patient age and curve magnitude increase. It has been estimated that every 10 degree increase in curve magnitude over 40 degrees results in a 10% decrease in flexibility; every 10-year increase in age decreases flexibility of the structural curve by 5% and the lumbosacral curve by 10%. Utilizing biplanar radiography, Matsumoto et al demonstrated that axial traction significantly reduces the frontal plane deformity. However the axial rotation was persistent in curves greater than 40°. In a study comparing the flexibility of proximal thoracic curves in response to side bending versus axial traction, Kirk, et al, found that the supine traction radiograph demonstrated greater flexibility of the proximal thoracic curve than the supine side-bending radiograph.

### Reliability of Line Drawing Methodologies

The reliability of the Cobb, Risser-Ferguson and Harrison Modified Risser-Ferguson methods of frontal plane abnormality was discussed previously in Sections VIII and X. The same reliability studies supporting these methods apply to the analysis of the stress films.

### Reliability of Patient Positioning

The reliability and reproducibility of the production of the radiographic image was discussed previously in this document and applies to the positioning of these patients and production of these films as well. However, care must be taken to either center the body part immediately below the scoliotic region or center the scoliotic curve apex to the center of the film.

### Diagnostic Capabilities

Orthopedists order stress films prior to surgical treatment to assess flexibility of the curve and to help determine level of fusion. Chiropractors, on the other hand, have the capability to assess the flexibility of the spine to ascertain an approximate maximum potential correction. This is the only diagnostic means to assess the flexibility or reducibility of a scoliotic curve.

### Validity of the Frontal Plane Scoliosis Stress Views

Stress films have shown good correlation for assessment of flexibility of a curve in that these views are predictive of post-operative curve correction. For example, Takahashi, et al showed that, “In thoracic curves, the postoperative Cobb angle was highly correlated with the preoperative Cobb angle in traction (r = 0.82). However, such correlation was much lower with lumbar curves (r = 0.54).
The reducibility of the thoracic curve by traction as expressed by the ratio to the original curve was dependent on the magnitude of the original curve \( (P = 0.005) \).\(^1\)

Kleinman\(^1\) found the difference in magnitude between the pre-operative prone push film and the post-operative film to be statistically insignificant \( (P = 0.34) \). In essence the more flexible a curve the more likely it will respond to operative treatment. This is also applicable to any conservative, non-operative intervention, including chiropractic.

**Outcome Investigations**

**Level IV Studies:**

Harrison, et al.\(^2\) reported on five patients who experienced a significant reduction of scoliosis deformity after Chiropractic Biophysics protocols. Their procedures were based upon results of a unique method of obtaining stress films. They reasoned that large spinal deviations, such as seen in scoliosis patients, may respond differently when two main motions are applied to the spine in opposite orders \( (A+B \neq B+A) \). This rationale is based upon the non-commutative property of finite rotation angles under addition.

Speiser et al.\(^2\) and Grice et al.\(^2\) reported on before and after outcomes in a few patients where AP lumbar stress bending films were used to determine treatment type and direction.
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F. Motion X-ray/Videofluoroscopy for Kinematic Instability Evaluation

RECOMMENDATION

Production and analysis of videofluoroscopic, cineradiographic and digital motion X-ray images are a well accepted part of clinical chiropractic practice. The PCCRP panel recommends these techniques in patients with acute and chronic traumatic injuries, after surgical intervention, that have failed to respond to clinical intervention, and in patient’s with pain reproduced by a specific spinal movement.


PCCRP Evidence Grade: Clinical Studies = B, C, D and Reliability, Biomechanics, and Validity = a.

Introduction

Fluoroscopy was first performed by Roentgen in 1895 during his seminar experiments with x-rays. Roentgen published his findings in the widely reprinted paper: W. C. Roentgen: About a New Kind of Rays. The following year, the fluoroscopic screen was invented by Italian scientist Enrico Salvioni. Shortly thereafter, Thomas Edison noted that calcium tungstate screens produced superior images to the barium platinocyanide used by Roentgen and Salvioni and the first commercially available fluoroscopes were produced.1

Some fifty years later, developments in fluoroscopic technology resulted in the image intensifier tube which permitted signal amplification, an improved image, a reduction in radiation exposure and output to a camera.2 When fluoroscopic images are recorded to film, it is referred to as cineradiography. When a videocassette recorder is used to record the output, the procedure is referred to as videofluoroscopy.

Active range of motion of the vertebrae in the spine may be visualized by way of videofluoroscopic joint motion study examination. By observing motion of the spine in weight bearing, it is possible to identify abnormal motion patterns. In many instances it is possible to visualize unstable and abnormal vertebral motion patterns by direct observation. By capturing video frames and measuring translations and rotations with a computer assisted method, it is possible to apply geometric threshold criteria to objectively identify structural abnormalities.

Motion patterns are observed and interpreted diagnostically. The fluoroscopic images are the result of an x-ray tube running a continuous exposure aimed at an image intensifier. The tube and image intensifier are usually mounted on a c-arm frame. A Charge Coupled Device (CCD) camera is mounted behind the image intensifier aimed at the tube. The output of the CCD camera is recorded on a videotape, DVD or computer hard drive. Compared to plain film exposures, videofluoroscopy with an image intensifier can produce a diagnostic image from the same kV with the mAS factor in the order of 1/20 to 1/30 of that for plain film. Accordingly, a videofluoroscopy assessment of the cervical spine can be obtained with a dose roughly equivalent to a plain film Davis Series of the cervical spine.

The CCD camera output is simultaneously viewed on a monitor while being recorded on videotape (or DVD). Individual frames from the video stream may be captured and evaluated in the same manner as plain film images. Depending on the format of the camera’s output, different lenses are used. For NTSC format video output, the first lens over scans the image creating a 4:3 aspect ratio and the second lens frames the image.3 DICOM format video output has a 1:1 aspect ratio.4
If computer analysis is being performed on captured images and plain film geometric values are being used, calibration of the output is required to account for the focal film distance (FFD) of the c-arm as well as output scale of the CCD camera and the pixel per inch (PPI) resolution of the images. However, this calibration will only affect translation (linear) measurements and not rotation (angular) measurements.

In 1991, The American Chiropractic College of Radiology and Council on Diagnostic Imaging released a position statement through the American Chiropractic Association regarding a protocol for the use of spinal videofluoroscopy (See Section VI). This position was also adopted by the Chiropractic College of Radiologists in Canada (See Section VI). While there have been significant technological advances since that time, there has been no modification to these original position papers. For example, minimum equipment recommendations as per the ACCR position statement included machines that were capable of generating at least 125 KvP at a range of 1-3 mA and a videotape recording device. Current machinery can operate at 100 KvP, 1-3 mA and produce better imaging than these “older” units and record the studies on videotape, DAT tape, DVD/CD-ROM or computer hard drives. Subsequently, other organizations such as the International Chiropractic Association have provided their own statements regarding the use of videofluoroscopy (See Section VI). It should be noted that as of March, 2006 position statements from the American Chiropractic College of Radiologists have been withdrawn from their web-site, pending review and possible update.

**Technique**

The technique of videofluoroscopy can be broken down into a number of components including an x-ray tube assembly, an image intensifier tube, a television camera, a videocassette recorder and a monitor.

Given advances over the last several years, it is prudent to distinguish videofluoroscopy from digital videofluoroscopy or digital motion x-ray, which primarily revolves around technological improvements to the image intensifier, monitor and recording components of the system. Since 1998, significant advances have been made in the use of charge-coupled-devices (CCDs) as well as amorphous silicon technology to allow for greater imaging ratios. This essentially translates to the need for less radiation to produce a better quality image. Image clarity, storage and review have also improved with the use of digital storage media.

**Cervical Protocol**

While videofluoroscopy can be used to assess extremities as well as the spine, the greatest advantage to the chiropractor will come from the assessment of spinal trauma and patients with pain upon specific movements only where no other objective findings are positive. Many fluoroscopic systems consist of an x-ray tube and image intensifier mounted on a 36 inch c-arm. This configuration is not well suited to assessment of the thoracic and lumbar due to patient thickness and close proximity of the patient’s skin to the tube. The 36 inch c-arm configuration is extremely well suited to assessment of cervical spine trauma and focal film distance calibration can be normalized to the 72 inch standard for impairment rating from flexion and extension views.
The full cervical videofluoroscopy protocol consists of:

1. **Lateral nodding**, involving lateral observation of cervical motion when the center of mass of the head is rotated posteriorly by raising the chin.

2. **Flexion and extension** involving lateral observation of the full active range of cervical motion in the sagittal plane. Freeze frame capture of representative neutral, flexion and extension may be obtained and digitized.

3. **Left Posterior Oblique Flexion and Extension** permits observation of the right intervertebral foramina through flexion and extension. This flexion and extension positions of this examination are not performed with plain film and provide a unique opportunity to appreciate the patency of the foramina as well as the integrity of the capsular ligaments.

4. **Right Posterior Oblique Flexion and Extension** permits observation of the left intervertebral foramina through flexion and extension. Comparison of oblique studies may be helpful in cases of unilateral radicular complaints.

5. **Anterior/Posterior Lateral Flexion** permits observation of symmetry in cervical motion as well as coupled spinous rotation, which is normally expected.

6. **Anterior/Posterior Rotation** permits observation of symmetry in cervical rotation in the upper cervical spine and may reveal abnormalities associated with capsular ligament injury.

7. **Anterior/Posterior Open Mouth Lateral Flexion** permits observation of alar and accessory ligament function.

**Clinical Utility of Videofluoroscopy**

As a preface to this section, it is important to understand that the use of videofluoroscopy/digital videofluoroscopy should be performed following an appropriate history, clinical examination, plain film radiographs and/or other additional diagnostic modalities. Furthermore, under many circumstances, persistent symptoms despite undergoing a period of conservative management will typically form part of the clinical decision to utilize videofluoroscopy/digital videofluoroscopy.

Among the early investigators of fluoroscopy whose studies are of relevance to chiropractic, Earl Rich and Fred Illi are considered pioneers. Videofluoroscopy has been used to observe and document the effects of cervical spine traction, evaluate cervical spine laminectomies, examine athletes presenting with pain, to assist in surgical planning, evaluate atlanto-axial rotatory fixation, examine the effects of cervical collars, characterize joint disorders in the cervical spine, study degenerative disease of the cervical spine and determine the effects of occipitalization and odontoid hypoplasia on spinal motion.

Videofluoroscopy can demonstrate the differences in the motion patterns of normal and pathologic spines. Schaff described cases of instability of the upper cervical spine demonstrated on videofluoroscopic studies.

According to Ochs, "Cineradiography, using film or videotape, is shown in a study of 34 painful or injured necks to be a valuable diagnostic tool. It is useful in fracture management, diagnosis of instability and demonstration of solid healing. A video tape system featuring instant replay, clear image and low radiation exposure was found to be ideal for routine use." Videofluoroscopy permits evaluation of suspected soft-tissue injuries of the cervical spine by demonstrating active ranges of motion. It is reasonable to anticipate that abnormal motion will accelerate degenerative changes in the spine and will complicate the videofluoroscopic analysis. The videofluoroscopic study is of greatest value in the detection of...
abnormal motion in patients who show otherwise normal spines on standard roentgenograms and before degenerative changes have occurred. The incidence of apophyseal joint abnormalities detected by videofluoroscopy is higher than that of plain roentgenograms. The videofluoroscopic study is of benefit in demonstrating either excessive or decreased mobility. It has proven to be of value in localizing the areas of abnormalities which correlate well with symptoms.

**Demonstrative Evidence of Trauma**

**Figure 2.** Anterior subluxation of C2, C3 and C4 due to posterior longitudinal ligament disruption.

**Figure 3.** Posterior subluxation of C4 and C5 due to anterior longitudinal ligament disruption.
Reliability of Measurement Methods

The reliability of videofluoroscopic interpretation has been examined in the literature. Croft studied the interexaminer reliability of the ability to distinguish between normal, hypomobile and hypermobile segments in 10 separate VF studies. Seven subjects were patients injured in auto collisions and three were uninjured “normal” subjects. There was good concordance between the 10 radiologists for the 10 VF studies of all cervical levels evaluated.

The reliability of videofluoroscopic measurement by computer assisted method has been reviewed by several investigators. In the case of video frame capture, measurement is performed on individual video frames and as such would be subject to the same reliability and validity as computer analysis of plain film roentgenograms. (Sections II and VIII) The reliability of fluoroscopic motion examinations analyzed by computer analysis has been reported.

Validity

Studies of the use of videofluoroscopy have compared the utility of video fluoroscopy to plain film roentgenograms and reports have been made regarding the superiority of videofluoroscopy to plain film roentgenograms in the detection of some pathology of the cervical spine. Videofluoroscopy studies have also been used to investigate normal and abnormal motion in the cervical spine. Videofluoroscopy has also been used to produce data on the lumbar spine.

In 1998, Okawa et al obtained fluoroscopic lumbar sagittal motion videos in volunteers (n = 13) and in patients with chronic low back pain (n = 8) and degenerative spondylolisthesis (n = 8) while the subjects bent forward from a standing neutral position (eccentric motion) and then returned to the original position (concentric motion). They reported that segmental instability influenced the whole lumbar motion in patients with degenerative spondylolisthesis. The patients with chronic low back pain did not show a significant difference when compared with the volunteers.
In 2001, Takayanagi et al\textsuperscript{95} studied 40 subjects (DS group) with degenerative L4-L5 segments compared to a control group of 20 subjects. The DS group was classified into 2 subgroups according to percentage of slip: DS group I, with a slip \(\leq 15\%\); and DS group II, with a slip > 15\%. Cineradiography was used while subjects flexed and extended in the sitting position. Motion analyses using cineradiography helped to explain the phenomena of lumbar spine kinematics. Based on continuous dynamic-motion analysis with cineradiography, large segmental angles and disordered motion pattern during the flexion-backward course in the DS group I was considered to be caused by segmental instability.

In 2004, Wong et al\textsuperscript{96} studied 100 healthy volunteers, including 50 men and 50 women, in lumbar flexion and extension. Lumbar flexion-extension was assessed with an electrogoniometer and videofluoroscopy simultaneously. Intervertebral flexion-extension of each vertebral level was calculated. Radiologic images of the lumbar spine were captured during flexion-extension in 10 degrees intervals. A linear-linked pattern of the motions was observed in different genders and age groups. No statistically significant difference in the pattern of motion was found between genders. However, statistically significant difference in the slope of curves was found at all lumbar levels in subjects whose age was 51 years or older.

Roentgenometric and geometric appraisal of vertebral biomechanics may assist in the clinical decision making process. Along with the analyses associated with static spinal views in the neutral position, dynamic motion analysis of the spine is useful in the detection of ligamentous disruption and unstable motion segments. Occasionally, fractures are revealed that are not visible on plain film views. Identification of contraindications to direct applied forces (Chiropractic adjustments and physical rehab procedures) is an important clinical consideration in case management. Threshold values for spinal instability have been published (Table\textsuperscript{1}):

\begin{table}
\centering
\begin{tabular}{|l|l|l|}
\hline
\textbf{Cervical spine instability} & White and Panjabi\textsuperscript{83} & 3.5mm translation  \\
& & \(11^\circ \) rotation (flex/ext)  \\
& AMA Guides 4\textsuperscript{th} \textsuperscript{84} & 3.5mm translation  \\
& & \(11^\circ \) rotation (flex/ext)  \\
& AMA Guides 5\textsuperscript{th} \textsuperscript{85} & 3.5mm translation  \\
& & \(11^\circ \Delta \) angulation /level on neutral  \\
& Kranes et al\textsuperscript{86} & 1.7mm atlas lateral shift (in vivo)  \\
& & 2.2mm at 72\textsuperscript{°} FFD (63)  \\
\hline
\textbf{Thoracic spine instability} & AMA Guides 4\textsuperscript{th} \textsuperscript{84} & 5mm translation  \\
& & \(11^\circ \) rotation (flex/ext)  \\
& AMA Guides 5\textsuperscript{th} \textsuperscript{85} & 2.5mm translation  \\
\hline
\textbf{Lumbar spine instability} & AMA Guides 4\textsuperscript{th} \textsuperscript{84} & 5mm translation  \\
& & \(11^\circ \) rotation (flex/ext)  \\
& & \(15^\circ \) rotation (flex/ext) L5/S1  \\
& AMA Guides 5\textsuperscript{th} \textsuperscript{85} & 4.5mm translation  \\
& & \(15^\circ \) rotation (flex/ext) L1-2, L2-3, L3-4  \\
& & \(20^\circ \) rotation (flex/ext) L4/L5  \\
& & \(25^\circ \) rotation (flex/ext) L5/S1  \\
\hline
\end{tabular}
\end{table}
The use of videofluoroscopy is recognized as an acceptable procedure in chiropractic practice by the following organizations in North America.

- The American Chiropractic Association
- The Canadian Chiropractic Association
- The Mercy Center Consensus Conference
- The International Chiropractic Association
- The Council on Chiropractic Practice
- The American College of Chiropractic Radiology
- The College of Chiropractic Radiologists Canada

Summary

In summary, the production of videofluoroscopic, cineradiographic and digital motion X-ray images are a well accepted part of clinical chiropractic practice. These imaging techniques are irreplaceable in the chiropractic office with regards to clinical relevance. There is substantial data on the reliability, predictive validity, and clinical utility of these imaging techniques.
References


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XI. Pediatric Radiographic Evaluation in Chiropractic

RECOMMENDATION

Production and analysis of X-ray images for the pediatric patient are a well-accepted part of clinical chiropractic practice. The PCCRP panel recommends spinal radiographs in these just as in the adult population. The guidelines put forth in Section II are recommended for pediatric patient populations.

Supporting Evidence: Clinical Studies III, IV, V, and Population Studies Class 2-4, Reliability Studies class 1 and 2, Validity Studies, and Biomechanics.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics, and Validity = a.

Introduction

Pediatrics is defined by Webster’s dictionary as “a branch of medicine dealing with the development, care, and diseases of children.” For this section, we define children as subjects in the age range of 1 day old and 18 years old, inclusive.

The foundation of an accurate chiropractic analysis and corrective care plan is based on a history, comprehensive examination, and appropriate diagnostic radiographs. Of the three, obtaining diagnostic radiographs in the pediatric chiropractic patient is the most difficult to accomplish due to patient movement. Patience by the doctor of chiropractic with the pediatric patient pays off by allowing visual examination only detectable by radiographic imaging.

Although radiation exposure in pediatric cases has been a concern in the past, the Radiation Hormesis section of this document details the fact that radiation risks from medical x-rays are near zero and the benefits are many. However, practicing chiropractors need to use appropriate judgment in the amount of X-radiation exposure.

In fact, the U.S. Bureau of Radiological Health emphasizes the importance of clinical judgment in selecting radiographic procedures. The Bureau also recognizes the right of the attending doctor to make an assessment of risk vs. benefit in determining what is in the best interest in care for the patient. If the doctor of chiropractic feels there is a reasonable expectation of obtaining information from a radiographic examination that would affect the care of a pediatric patient, the potential radiation hazard is not a primary consideration.¹

The following general guidelines are suggested:

1. The outcome of the radiographs study will be used in determining the nature of care administered.
2. If possible, obtain copies of prior radiographs (from other office(s)).
3. The highest film speed and cassette combination should be used when possible. Some situations may require lower screen speed to increase detail.
4. Use the manufacturer’s recommended time and temperature for processing.

General Considerations

When working with a young child, the chiropractic staff should make the x-ray procedure as comfortable as possible. The first step in desensitizing a child to the experience is to explain what you plan to do in terms the child may comprehend. Show and tell allows the child to
become comfortable with this procedure. The more compliant child will hold still for the
necessary time to obtain a diagnostically useful film.

Radiographic procedures for children should include safety precautions. Shields should
be used to protect areas sensitive to radiation when ever possible. If the shield will cover an area
which needs to be visualized, then the doctor must make that determination.

Children should not be left alone during the radiographic evaluation. The survey should
be performed by two people working together, to avoid the child being left alone during the
radiographic evaluation. A staff member or parent of the child may be used in this position. The
films should have the correct the correct name and correct side markers, and the date and time of
the examination should be clearly marked.²

Reasons for Radiographic evaluation in children

Vertebral subluxations can be a serious health hazard at any age, the child is no
exception. Radiographic examination provides vital information not available by any other
means. During birth especially when forceps are used, the cephalad traction may cause tearing of
ligaments, muscles, discs, and the spinal cord. This type of traction to the newborn’s head and
spine may subluxate the condyle-atlas, the atlas-axis and the lower cervical vertebrae. Vacuum
type extractions are another type of cephalad traction. C-section type births may cause injury to
any area of the spine. Less than ideal birth presentation, as with variations from a vertex such as
brow or facial delivery, apply aberrant forces to the skull, cervical and thoracic spine. The
newborn’s pelvis and lumbar spine may be subluxated in breech births. Retrolisthesis and
anterolisthesis of the cervical spine may be caused if tremendous force is applied to extract the
newborn. Protracted as well as fast deliveries also deliver abnormal stresses to the skull and
spinal structures.

Upper cervical instability along with atlas inversion into the foramen magnum can cause
incomplete or temporary compromise to the blood supply of the upper spinal cord and brain
stem. This can cause impairment of the respiratory centers in the medulla as seen in chronic
intermittent hypoxia present at autopsies of SIDS cases.³ ⁵ ¹⁰ ⁶-¹⁰⁹

"Damage to the reticular nuclei just dorsal to the inferior olives of the brain stem can
cause respiratory depression, which accounts for a large percentage of neonatal deaths, and
damage to the vagus nerve may play a role in another type of infant death, termed Sudden Infant
Death Syndrome (SIDS)."⁴ Some additional injuries to newborns may be found in some recent
literature and texts.⁵ ¹⁴

There are a multitude of literature reports on injuries that are specific to birth and impact
traumas.¹⁵-⁷⁵ The clinician should be aware of these possible injuries and a radiology
examination may reveal if the child has sustained any of these.

The above possible injuries to the newborn’s upper cervical spine indicate the need for a
minimum pediatric cervical series, which includes a lateral cervical and an AP Nasium upper
cervical view. The nasium view is recommended over the AP cervical radiographic view as the
AP cervical view does not depict the alignment of the C0-C1-C2 complex.

Besides birth traumas, children of any age may be subjected to falls, pulling by a sibling
or parent, accidents and even abuse. Since the average toddler falls down many times in one day,
this and any of the previous insults may subluxate/misalign the child’s spine. School age
children participate in contact sports which may impact the spine and cause abnormal alignment.
Gymnastics, ballet, and football along with many other activities may twist, torque or otherwise
cause abnormal spinal alignment, which cause abnormal physiology, abnormal biomechanics,
abnormal neurological function, disc injuries that go unrecognized,\textsuperscript{54} and cartilage breakdown with hypermobility.\textsuperscript{70,71} In many cases, abnormal spinal alignment does not cause an immediate symptom, but the condition compromises nervous system integrity which may influence organ system function and general health.\textsuperscript{72-73} This is the cross-sectional view of a patient versus the longitudinal view. The information gained from chiropractic radiographs far outweighs the inherent dangers, since the risks of medical/spinal x-rays are nearly zero or may even have a health benefit.

**Pediatric Radiographic Considerations**

Radiographs commonly used in the chiropractic profession are of the cervical, thoracic and lumbar spines. Radiographs in children are taken in a similar manner as adult with some exceptions since children who are newborns and up to age 12 months generally cannot stand. Depending on the child’s age the x-rays may be taken with the child sitting, supine, prone, standing, leaning against the bucky, held by a shielded attendant, or ‘bundled’ if the infant can’t be held still without these restraints. Head clamps or lead gloves are used to hold the child’s skull or body in position. Ensuring patient compliance is of great value when x-raying a child. Therefore a pacifier, favorite toy, or blanket may be used during the procedure.

X-radiation safety is important for all ages and during imaging of a child. Care should be taken to shield areas not being examined. Small focal spot, collimation, speed of film, and body shields may be in combinations to protect the child. These items are taught in all Chiropractic Colleges and are the individual doctor’s responsibility.

Pediatric radiographs have several inherent differences when compared to adult radiographs. In the newborn, vertebrae have three ossified parts which are united by cartilage (Figure 1). The cervical region is the last to ossify. The ossification of the posterior ring of C1 is usually completed by age three. The ossification center at the apex of the dens is not visible until the second year. Between the ages of four and seven the odontoid of C2 fuses to the body. Closure of the neurocentral union between the pedicle and the vertebral body does not occur until the fourth to fifth year. At about age 15, the secondary ring centers of Axis-C7 fuses with the primary body centers.
Due to the fact that the infant has a great deal of unossified bone, measurement landmarks may differ from that of an adult. On the lateral radiograph, the young child’s vertebrae appear to have step-like recesses on the anterior edge (Figure 2). This is due to an annular recess that surrounds the entire body and is filled with cartilage. These indentations are occasionally seen on the lateral margins. As the child grows, the vertebral bodies become more rectangular (Figure 3).

The facial bones of the infant are compressed relative to those of the adult. The growth of the facial bones in the adult gradually increases the angle between the radiographic base line and the pediatric base line. This will affect the angle at which the nasium radiograph is taken. The infant’s x-ray will have a smaller angle whereas older children will have a slightly larger angle.
Figure 4. Left is a neutral lateral cervical of 5-year old male showing a pseudo-subluxation of the posterior vertebral body margin of C2 relative to the posterior vertebral body of C3; the spinal-laminar line is intact. This is still an abnormal finding on a neutral lateral cervical as pseudo-subluxation is only normal on a flexion positioning film as in the figure on the Right.

Due to the normal hyper-mobility of the cervical spine in children, care must be taken to accurately analyze the lateral cervical radiograph. It is generally a normal finding to see a slight forward shift of the posterior vertebral body of C2 on C3 in flexion. This is known as “Pseudo-subluxation” and is considered a normal variant. The differential diagnosis (DDx) is the spinolaminar line is intact with a pseudo-subluxation, whereas it is not with a true subluxation. However, this ‘Pseudo-subluxation’ should not be present in the neutral lateral cervical. See Figure 4. Also, C3 may shift forward on C4 in flexion. In a normal radiograph, this forward shift of the vertebrae disappears in extension. If it persists, it is an abnormal finding.

The lumbar spine is the first to ossify during the first year of life. Some of the vertebrae are still cartilage until puberty, this includes the upper and lower surfaces of the bodies, the tip of the transverse, and the spinous processes. The sacrum may not fuse into a single mass until the 12th and 25th year.

In 2005, Biedermann wrote a pediatric text for the Manual Therapist discussing pediatric radiology in some detail. He stresses the fact that “the cervical region of the vertebral spine is the most complex and also the functionally most important in children.” He also stated that “there are cases where X-ray evaluation in the lumbar and pelvic girdle is essential.”

Biedermann also noted that some in the manual therapy field take “the obvious and radial consequence to disregard X-ray analysis completely.” He stated that “this argument is facilitated by the fact that many of those applying manual therapy to the vertebral spine often to not have ready access to radiographs, as is the case for many physiotherapists.”
From Biedermann, “[Children] show a complex pattern of inborn and acquired features, the main morphological problems in newborns are congenital variants found in this evolutionarily volatile region.” “A second aspect of the functional analysis of the X-ray pictures of small children is the dominance of functional over morphological details”. “In the small child – and even more so during the first year – it is more often the (mal) function which determines the way morphology will differentiate.” We see more and more examples where a timely intervention mobilizes the functional situation and imminent morphological pathology could be averted. The functionally fixed posture results in a morphological response. This is one major reason why the functional analysis of the X-ray pictures is of such paramount importance in dealing with our young patients.76

Biedermann also noted that, in the pediatric patient, important anatomical deviations are too elusive to be found clinically and thus, radiographs are needed. He also stated that it is not possible to find out beforehand, either in the medical history or findings from palpation, where it would make sense to take a radiograph and where not. He noted that it is not possible to define pediatric “risk groups”. He stated that it is not possible to determine who then should have a radiographic examination, nor possible to exclude groups of pediatric patients.

Radiographic Imaging Views

There are some additional reports of C0-C1-C2 anomalies and pathologies that may apply to the pediatric upper cervical spine.79-83 These situations may require additional radiographic views in pediatric cases. To completely determine a child’s problem, cervical radiographs may include the lateral cervical, nasium, A-P open mouth, Vertex, Base posterior, flexion-extension and/or obliques. Thoracic radiographs include lateral thoracic, A-P thoracic, flexion-extension, and/or oblique views. Radiographic studies of the Lumbar, sacrum, and pelvis may be taken from the lateral, obliques, and A-P views. The views necessary to determine appropriateness and corrective chiropractic care program is determined by the attending chiropractor and is done on a case by case basis.

Indications Specific to Pediatric Radiograph

In addition to the “Indications for Radiography in Children and Adults” provided in Section I of this document, there are several indications for spine radiography that are specific to pediatric cases. These include, but are not limited to the following:

1. Seizures
2. Difficulty breathing
3. Colic
4. Delayed suckling
5. Delayed bowel movement
6. Delayed awareness, such as following with the eyes
7. Delayed physical maturity, such as rolling over, crawling, and/or walking
8. Delayed speech
9. Lazy eye, one eye rotated inward or outward.
10. Torticollis
11. Any fixed posture (e.g., abnormal lateral cervical curvatures, scoliosis, extension postures)
Pediatric Outcome Studies Utilising Spinal Radiography

In 2004, Bastecki et al\textsuperscript{84} reported improvement in an 8 year pediatric case with ADHD. At 5 years of age the child was diagnosed with ADHD and treated by an MD pediatrician unsuccessfully with Methylphenidate (Ritalin), Adderol, and Haldol for three years. At age 8, the child received 35 CBP chiropractic treatments over the course of 8 weeks. A change from a 12° C2-C7 kyphosis to a 32° C2-C7 lordosis was observed at post-treatment. During chiropractic care, the child’s facial tics resolved and his behavior vastly improved. After 27 chiropractic visits, the child’s pediatrician stated that the child no longer exhibited signs and symptoms of ADHD. The authors’ stated that changes in structure and function appear to be related to the correction of cervical kyphosis.\textsuperscript{84}

In 2000, Aguilar et al\textsuperscript{85} reported on a cohort study of 26 autistic children. The children were put on a 9 month care program of adjustments with Grostic and Orthospinology techniques. Objective data were collected through brainstem evoked potential (BESP’s) recordings, pre and post x-ray films, a dual probe infrared heat recording graph instrument, and a supine leg length check analysis. Subjective data were collected through both a Modified Autism Checklist and Childhood Autism Rating Scale (CARS). Preliminary data collected indicated a correlation with the atlas adjustment and behavior improvements in autistic children.

In 2000, Mayer Hunt\textsuperscript{86} reported on a case study of a twelve year old girl with a 7 year history of a right cystic hygroma and concomitant daily morning neck pain and headaches. Her history involved 4 surgical procedures which failed to contain the mass or relieve her severe sinus drainage. Cervical X-rays were performed with a noted loss of lordosis. Orthospinology technique films of the nasium/vertex views were analyzed with C1 left 1° with 3° of anterior rotation C2 left 1° with 12° rotation. Lower cervical angle was measures at 1° to the right. Care was delivered at 3x4 weeks then 2x2 weeks, 1x8 weeks then 2x/month for 8 months. Following seven months of chiropractic care, the mass remised and had not returned on two years of follow up. The neck pain and headaches also resolved.

In 1998, Killinger and Azad\textsuperscript{87} reported on a case study of an 11 month old male with severe complicated late onset infantile colic. The infant had been unable to consume solids for a period of four months and suffered from severe constipation. In addition the subject demonstrated extreme muscular weakness and lack of coordination. The baby was unable to crawl, stand, or walk and was greatly unresponsive to his surroundings. X-rays performed were AP, Lateral and APOM cervical spine with a confirmed presence of atlas vertebrae malposition (ASLA) as determined by radiographic line analysis discussed by Roberts in his 1994 paper. Two toggle recoil adjustments were delivered with improvements in the ability of the child to hold his head up, play happily for 2.5 hours without weakness or crying. The infant slept through the night which had not been seen prior to the adjustments. The parents also noted the baby was more alert, overall with limb motion – more active and more coordinated with an active interest in his surroundings. One week after presenting, the baby was able to eat his first solid food in five months and keep it down as there was no vomiting. Bowel movements occurred without the aid of an enema.

In 1997, McCoy et al\textsuperscript{88} reported on a case study of a 4 year old child presented after trauma with a “cock-robin” position which is typical for an atlantoaxial rotary fixation. Radiographs of APOM, APLC and lateral views were obtained. A left lateral head tilt with right cervical spine convexity was noted. Asymmetry of the paraodontid spaces were noted with an atlas overhang of left lateral mass on C2 by 3mm. Axis was rotated spinous right. The lateral projection noted a tilt of atlas. Stairstepping of Georges line began at C3. Anterior displacement
of posterior cervical line is noted at the posterior tubercle of the atlas and posterior displacement of the spinolaminar line was noted at C2 and C3. Adjustments were delivered and within two weeks following spinal adjustments, the patient returned with complete resolution of symptoms.

In 1997, Hyman\textsuperscript{89} reported on a two month old with a history of obstetrical brachial plexus injury at the level of C5-C6 presented for chiropractic care. Radiographs were obtained by AP full spine and lateral spine views. A left diaphragmatic hemiparesis was noted. Palmer Upper Cervical Specific line analysis and the Gonstead technique line analysis revealed a C1 misalignment on the right (ASR), a PI misalignment of C5 and a right PI ilium. Chiropractic care was delivered accordingly to the listed areas. Detailed progression with observations, were noted with resolution of the infant’s condition after 8 visits.

In 1996, Anderson-Peacock\textsuperscript{90} reported on a case series of children with headaches. Case one did not have X-rays. Case two involved a 4 year old with the medical diagnosis of classical migraines at a frequency of one per week with duration of one full day. He had X-rays taken with a left translation of the head relative to the thoracic cage, an anterior cervical gravity line; C1 left lateral, C6 posteriority relative to C7, superiority of C0-C2 on the right and C6-T4 also on the right. T2/3 were rotated spinous right, L1-L33 rotated spinous left. Adjustments were delivered by Diversified technique and after 6 weeks of care, there were no further migraines.

Case three\textsuperscript{90} was of a 7 year, 11month old, who presented with cervicogenic evening onset frontal headaches precluding her from falling asleep. These occurred at a frequency of 1 to 2 times per week. Cervical x-rays found kyphosis from C4-7, C1 lateral right, C6 PI and T2-4 rotated spinous right. Diversified technique was used and subsequent to two weeks of care, there was a reduction of headaches. After follow up at four months, she had experienced a total of two headaches, and as an additional improvement, she had no ear pain which was also noted in the history.

Case four\textsuperscript{90} was a 13 year 11 month old who was medically diagnosed with migraines for 5 years at a frequency of 2 migraines per month. Cervical X-rays noted kyphosis of the cervical spine with anterior cervical gravity line. C0-C1 were right lateral, C3 and C6-7 were in a relative posterior position, C5 was rotated spinous left and T2 rotated spinous right. Vertebral body unleveling was noted at T1-3 inferior on the right. Diversified care began and within two weeks he experienced no headaches until a fall on his coccyx at two months at which time they returned. They were reduced again after three weeks of care.

Case five\textsuperscript{90} was a 15 year old with general and orbital headaches of a ‘several times per week’ frequency over a period of 10 months. Bilateral eye pain with numbness and paresthesia, a recurrent stiff neck, left sinus pain and numbness over the left maxillary sinus region for a number of weeks was also noted. Specialists had ruled out other pathology. Cervical X-rays APOM, APLC, and Lateral noted an interruption of George’s line at C4-5 with anterior cervical gravity line. C1 was left lateral, C6PI, T1/2 spinous rotation right. Diversified adjustment was delivered and within two weeks she had no facial numbness and no headaches and greatly reduced eye pain.

In 1996, Hyman\textsuperscript{91} reported on a case of a child with petit mal seizures. Uncontrolled by medication petit mal seizures of 4-6 per hour and toeing-in with leg pain were noted on the first visit. Additionally, involuntary movement of the head and upper extremities was noted. X-rays noted a double apex curve measured by Cobb. The lumbar curvature was 10 degrees with the apex at L3 and the thoracic was 7 degrees apex at T5. The spinal subluxation listings were ASRA, T4 PI with spinous rotation left, L3 PL and pelvis left PIEX and right ASIN. Table assisted low force high amplitude adjusting was performed on a side posture drop headpiece.
using the Palmer Toggle recoil technique. These adjustments were given for upper cervical and full spine adjustments on a segmental drop table using Thompson technique. The frequency of seizures dropped to 2-3 per two hours by the third visit and by the tenth visit dropped to 1-2 seizures every three to four hours. After 2 months of chiropractic care, the patient was off seizure medication, and experiencing zero to 1 seizure per day. In addition the leg pain resolved and toeing-in reduced.

In 2004, Ressel, a DACBR, and Rudy reported on an exhausting review of 650 pediatric patients under chiropractic care. In addition to examination and other diagnostic procedures, radiographs were obtained on the patients. The authors describe a Pelvic Distortion Subluxation Complex (PDSC) that was seen in 96% of the children. It was reported that the PDSC was “a common denominator in complaints plaguing our sample of children.” They also discuss that the PDSC were correlated with complaints that were mainly somatic, visceral and immune related.

Alcantara et al report on a 2-year old girl who presented with her mother for symptoms associated with recent onset myasthenia gravis following a motor vehicle collision. Adjustments were provided to the cervical and sacral spines based in part upon specific spinal listings measured form AP radiographic images of the spine. The toddler responded well to care and was free of symptoms following 5 months of care. For the first 3 ½ months of care the girl was adjusted 2-3 times a week. Comparative x-rays were taken and evaluated with reported improvement.

In 1997, Peet reported a pediatric case of an 8 year old with A.D.D. Chiropractic evaluation and care (CBP Technique for 4 months) were initiated after three years of traditional medical care consisting of Ritalin™ and Prozac™ and behavior modification. Spinal radiographs were obtained: (a) lateral cervical showed anterior head translation and a reduced atlas plane line to horizontal (10°), (b) the nasium revealed an Against pattern of left UA = 2° and right LA = 6.5°, with a left CD angle = 8° at mid neck, and with a UTC angle = 6° at T2 area. The child’s head posture was a right lateral translation, right lateral flexion, and anterior head translation.

There was a left lateral flexion of the thoracic cage. After 12 visits over 2 months (2x week for 1 month, 1 x week for 2 months), post radiographic measurements were: UA = ½ °, LA = 1°, CD = 0°. After 3 weeks, the child’s parents discontinued all medications. After 6 weeks, the child’s behavior was graded in a school setting. He had improved in cognitive skills, concentration on tasks, was less aggressive, and improved ability to control his emotions. The child showed marked improvement for 4 more months.

In 1997, Peet reported a pediatric case with chronic respiratory infections, ADHD, and chronic fatigue. The 8 year old male had suffered a birth trauma (forces and vacuum extraction) and was a premature baby. He was diagnosed by his MD with ADHD, and had constant throat congestion and raspy voice, seizures at time of ear infections, flat feet, chronic fatigue, loss of physical stamina, and low back pain which started immediately after birth. He was on Phenobarbital™ for seizures. The CBP Technique was utilized for the postural examination, radiographic examination, and chiropractic treatment (3x week for 3 weeks, 2x week for 4 weeks, 1x week for 10 months). The postural examination revealed: (a) large right head translation, (b) anterior head translation, (c) right lateral flexion of the thoracic cage, and (d) right lateral translation of the pelvis. The radiographic examination showed: (a) lateral cervical: Tz = 24 mm, atlas plane line reduced 30° (measured 0° to horizontal), and a kyphotic cervical curve from C2-C7, (b) AP Cervico-thoracic: left LA = 6°, with a left CD angle = 2.5° at mid neck, and with a UTC angle = 5.5° at T2 area, (c) AP lumbo-pelvic: HB angle at sacral base
67% reduction in all angles on the AP cervico-thoracic view. His posture drastically improved, he could sit for much longer, he no longer talked with a raspy voice, he no longer had back pain, his mental disposition improved, and he no longer got sick with ear infections.95

In 1997, Peet96 reported on a 3 year old female pediatric case with indigestion and pain, which symptoms started after a fall off her bed onto the floor. The parents brought the child for chiropractic care (CBP technique) 2 days after the fall. Postural examination revealed: (a) left lateral head translation, (b) left head lateral flexion, and (c) left thoracic cage lateral flexion. Radiographic evaluation revealed: (a) decreased atlas plane line to horizontal on the lateral cervical (only 10°), (b) nasium: UA = right 2°, LA = right 4°, and CD = left 7°. The patient received daily visits for one week, 3 times per week for 2 weeks, 1 time per week for 8 weeks, and 2 times per month for 3 months. After the fifth visit, the patient had fewer stomach pains and her appetite returned. After 2 weeks, her stomach pains had ceased. Post examination at the 10th visit, with overall improvement measured in the head region and thoracic to pelvis region.96

In 1997, Marko97 reported on a 10 year old boy with asthma. The boy took medications to control his asthma. Postural examination revealed: (a) significant extension and posterior translation of the pelvis compared to the feet, (b) right lateral flexion of the thoracic cage, (c) right translation of the thoracic cage, (d) anterior translation of the thoracic cage, (e) head flexion, (f) anterior head translation. Radiographic examination revealed: (a) +Tz anterior head translation of 25 mm on the lateral cervical, (b) nasium: LA = left 2°, and CD = left 4°. Chiropractically, the boy was treated 3 times per week for 3 weeks, 2 times per week for 2 weeks, 1 time per week for 4 weeks, and 2 times per month for 2 months with CBP Technique. At the end of 21 visits, the patient was much improved, had less congestion, less asthma symptoms, and less upset stomachs.

In 1997, Peet98 reported on an 8 year old female with chronic asthma. Prior to chiropractic care, the child used Beclovent™ and Albyterol™1-3 times daily. These asthma symptoms appeared after a fall in which the child dislocated her left elbow at 5 years of age. Postural examination revealed: (a) left lateral flexion of the thorax, and (c) anterior head translation. Radiographic examination with the nasium projection revealed: (a): UA = right 1°, (b) LA = right 1°, and (c) CD = left 5°. Eleven visits after initiation of CBP Technique care, the child’s asthma symptoms ceased. In the next 5 months, she only experienced one allergy induced asthma attack. She has been drug free since that time. Post radiographic evaluation revealed: UA = 0°, LA = ½ 0° and CD = left 1°.

In 1996, Peet99 reported on a pediatric case of a 5 year old with reoccurring Otitis Media. In the previous 2 years, the child had reoccurring middle ear infections every 3 to 6 weeks and the child had undergone antibiotic medical care. For the current episode of Otitis Media, the parents opted for chiropractic care (CBP Technique). The child’s posture examination revealed (a) anterior head translation, (b) right axial head rotation, (c) right head lateral flexion, (d) left lateral flexion of the thoracic cage. Spinal radiographs were obtained: (a) lateral cervical: +Tz Head translation, (b) reduced atlas plane line to horizontal (10°), (c) nasium: left UA = 1° and right LA = 7°. Post nasium x-rays measured: (a) UA = 0°, and (b) LA = ½ 0°. After the first adjustment, the effusion stopped. In the following 6 months, the child had only one more ear infection with mild effusion and chiropractic care was used, not antibiotic therapy.

In 1995, Peet100 reported on a cohort study of 8 pediatric cases with asthma. Peet reported improvement in the asthma in 7 out of these 8 cases utilizing CBP technique. Twelve pediatric patients (ages 4-12 years) self selected from an advertisement for a clinical trial on asthma, while
8 subjects completed the study. All participants had a medical diagnosis of asthma, and were taking at least 2 types of medication: Ventolin, Intol, Preventil, Nasal crom, Benedryl, Beconase, Prednisone, Theophyline, and Cromdyn. Each subject had a posture examination with the MetreCom and a series of CBP x-rays of the cervical and upper thoracic spine. Radiographic displacements from normal were reported in tables. All subjects had anterior head translation ranging from 9mm-30mm. By adding UA, LA, and CD angles on the nasium views from the tables, pre- and post-alignment changes were listed in percentages for all 8 cases (82%, 37%, 89%, 55%, 80%, 27%, 76%, and 44%). Seven parents stated that their child reduced the need for medication. Four parents reported that their child did not now require medication. Additionally, two parents reported that their child no longer needed an inhaler to control their asthma, while only one parent reported no improvement.

In 1994, Peet reported a pediatric case with brachial plexus injury in an infant (12 months old) with Down’s syndrome utilizing CBP Technique. The one year old male had suffered a brachial plexus injury at birth. The infant had lack of upper body control, especially arm movement, night time wakefulness lasting several hours, unable to fed himself due to lack of ability to move hand to mouth, and unable to sit up. The mother reported a difficult birth with the child in intensive care after birth. The infant had received previous physical therapy for 11 months. Posture examination revealed (a) right head lateral flexion, (b) right lateral flexion of the thoracic cage. Radiographic examination revealed; (a) lateral cervical: mild atlantoaxial instability, (b) nasium: left UA = 3°, right LA = 3° and left CD = 6°. The patient received chiropractic care for 4 months (3x week for 3 weeks, 1 x week for 3 months, and 2x month in the last month). At the 3rd visit, the parents reported that he was able to lift his arm for the first time in his life to wave and that he could bring a cheerio to his mouth with his hand. Over the following 2 months, the child only had two sleepless nights. After 6 weeks of care, he could sit up and began to crawl. After 3 months, the child’s abnormal posture completely resolved.

In 1994, Garde reported on a pediatric case with asthma. He also provided a review of asthma and spinal manipulation. The case was of a 6 year old body who had suffered from asthma since 1 year of age. The boy coughed continuously and had shortness of breath. He was diagnosed by an MD and given Beclovert and Verytolon, which he had to use 3 times or so per day. His posture examination revealed: left head translation, left head rotation, left lateral flexion of the rib cage, both shoulders rounded forward, pelvic tilt (+Rx), and knees extended. Radiographic examination reveal: (a) 35° cervical lordosis of C2-C7, but with 20mm of +Tz head translation, (b) nasium view: 5° UA of atlas to skull, and (c) thoracic views: box like appearance associated with abnormal breathing patterns. CBP Technique was utilized (9 visits in 1st month, 7 visits in 2nd month, 10 visits in 3rd month, 6 visits in 4th month, 4 visits in 5th month, and 4 visits per month for the next 6 months). After chiropractic care, the boy runs, plays sports, rides his horse without needing medication. His mother reports that she cannot remember when he last used his inhaler.

In 1994 Kent reported on two pediatric cases with vertebral body deformities. In case 1, a 10 year old boy with a painful limp was provided a radiology examination. On the lateral lumbo-thoracic view, a marked angulation of L2 on L3 was observed with focal kyphosis and a seemingly dislocation in flexion and anterior translation grade 4. Lateral cervical revealed odontoid dysplasia. In a 16 year old boy, with lower thoracic pain, AP and lateral radiographs were obtained. The lateral thoracic radiograph revealed severe wedging of three segments with increased kyphosis at that region. Kent discussed these deformities as hereditary, developmental...
and/or from trauma, but could be from infection, neoplasm, or metabolic disease, but radiographs are needed to find and diagnose these conditions.

In 1994, Marko\textsuperscript{104} reported on a pediatric case with constipation. A 10 month old female was provided chiropractic care utilizing CBP technique for constipation that started at when solid foods were introduced at 6 months of age. The patient was a Frank Breech position delivery. At one point the baby became impacted and emergency care was necessary. At her first chiropractic visit, the patient could not yet crawl and went a week to ten days between bowel movements. Parent reported that she had a bowel movement only by being in a warm bath and by parental massage of her abdomen, and she would cry and scream during the process. By hanging the baby from her arm pits and observing her lying supine over time, a postural analysis was performed. She had lateral flexion of the pelvis, anterior translation of the thoracic cage, and left lateral flexion of the head. Radiographic angle revealed: (a) HB sacral tilt angle of 7°, (b) nasium view: UA = 1° left, LA = 5° right, and CD angle = 3° right. She was seen 3 times per week in the beginning, but needed more frequency depending upon her posture. After the second visit, the child had a bowel movement by herself. After 2 weeks, the girl had regular bowel movements every 2-3 days by herself without pain. During this time, her muscle tone improved and she began to crawl. At 23 months of age, she began to walk and had totally normal bowel movements each day.

In 1994, Mawhiney and Mawhiney\textsuperscript{105} reported on a Down’s pediatric case with scoliosis. The patient was a 10 year old boy, who had staggered gait, disturbed speech, poor coordination, and slow papillary response. The boy had been seen by a medical doctor who prescribed a brace for the scoliosis, which was progressing (increase from 42° to 52° thoraco-lumbar curvature and 42° to 47° thoracic curvature). The MD suggested Harrington rod surgery. AP full spine radiographs were obtained standing and hanging. Hanging views revealed a 25% reduction in the T5 apex angle and nearly 50% reduction in the T10 apex angle. Pelvic displacements decrease on the hanging view. Right Logan Basic contact was provided, with a heel lift in the right shoe, adjustments at the the apexes of the curvatures, and use of Leander traction/distraction with a scoliosis strap. From July 22, 1994- September 2, 1994, the patient was given 17 treatments. Instead of progressing, on post x-ray, the thoracic curve reduced from 45° to 41°. The Post standing AP full spine view revealed better alignment of the odontoid over the sacrum. The patient has a longer attention span, more energy, and more flexibility.

**Conclusion**

Through the proper use of radiographic imaging the doctor of chiropractic may determine the appropriateness of chiropractic care for the pediatric patient as well as a course of correction of vertebral subluxations. Visual inspection of the spine and related areas by radiographic study provides information that may not be available by other means. The attending chiropractor should decide what is in the best interest in care for the patient. Radiographic evaluation of the infant and child is a privilege and responsibility that the chiropractor is trained to accomplish. This is why Chiropractors have x-ray privileges mandated by State and Provincial Laws in various countries.
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XII. The Presence of Spinal Subluxation, Any Axial Pain, or Radicular Pain are Indications for Radiographic Evaluation

Introduction
In Section II of this document, 27 indications for spine radiography in children and adults were listed. Some of these indications were:
1. Somatic pain
2. Headache
3. Radicular pain
4. Pain during motion of the spinal or extremity joints.

Subluxation Defined
In a previous section (V), the six types of Structural Spinal Subluxation were delineated. These 6 types of subluxation are mechanical descriptions for the allowable spinal displacements.
1. Segmental subluxations,
2. Postural main motion and coupled motion;,
3. Snap-through buckling in the sagittal plane,
4. Euler buckling in AP/PA view,
5. Scoliosis,
6. Static or dynamic segmental instability.

Subluxation can be simply thought of as an alteration of the normal joint structural alignment and/or function, since altered position causes altered motion. Vertebal subluxation, of course, is specific to any of the five regions of the axial skeleton (cervical, thoracic, lumbar, sacral, and pelvis). Extrapinal subluxation denotes the articulations of the extremities, including the foot, ankle, knee, hip, shoulder, elbow, wrist, hand, anterior ribs, and head (TMJ). Joint structure is defined as the alignment of two or more articulations of the musculoskeletal system. Joint function is defined as the kinesiological motion patterns comprising study of kinematics and kinetics to investigate joint motion and integrity. With these definitions in mind, radiological indications for the assessment of spinal subluxation will be discussed herein.

Nerve Supply to the Disc
Until the 1980s, it was conventional thought that the spinal discs and ligaments were not innervated. Since that time, numerous papers have been published establishing the nerve supply to the intervertebral disks, ALL, PLL, facet capsular ligaments, ligamentum flavum, intertransverse ligaments, interspinous ligaments, and the supraspinous ligaments. It is now known that the outer 1/3 of the intervertebral disc is innervated by the sinuvertebral nerve, which unions with branches from the Grey ramus communicantes (Figure 1). The upper dorsal root ganglion sensory fibers innervate the dorsal portion of the discs via the paravertebral sympathetic trunks, while the sinuvertebral nerves, from the lower dorsal root ganglions, innervate the same dorsal region of the disc. The sinuvertebral nerve is a recurrent branch from the ventral ramus of the spinal nerve and it anastomoses with sinuvertebral nerves of adjacent segments. Nerve ingrowth along zones of granulation has been shown to extend into the nucleus pulposis of degenerated discs.
Nerve Supply to the Spinal Ligaments

Various spinal ligaments have been shown to possess innervation. The lumbar spinal dura mater has been shown to possess innervation. Kallakuri, et al described, “numerous fine nerve fibers and some small bundles were demonstrated in both the dura and the longitudinal ligaments.” The ventral dura was more richly innervated than the dorsal. The authors also concluded that, “the significant number of putative nociceptive fibers supports a possible role for these structures as a source of low back pain and radicular pain.”

The thoracic spine as with the other regions of the spinal column is surrounded by ventral and dorsal nerve plexuses which are interconnected. The ventral plexus consists of plexuses of the anterior longitudinal ligament. In the thoracic region, the ventral plexus is also connected to the nerve plexuses of the costovertebral joints. The dorsal plexus is comprised of the nerve plexus of the posterior longitudinal ligament (PLL).

The PLL in the cervical spinal region has been shown to receive sympathetic innervation. Sensory fibers in the cervical dura mater and the PLL have different sensory and sympathetic innervations. The ventral spinal dura contains a dense longitudinally running plexus receiving its contents from the sinuvertebral nerves, the nerve plexus of the PLL and the nerve plexus of the radicular branches of segmental arteries. The dorsal region of the dura mater is less richly innervated, with fibers extending up to eight segments, with significant overlap between adjacent nerves.

Mechanisms of Pain

In this present Section XII, the rationale for the inclusion of pain indications for radiography are discussed. The necessity for radiological examination in the presence of pain is further explained by knowledge of publications in the literature from several different fields of study including:

1. Neuroanatomical Research
2. Neurophysiological Research
3. Surgical Studies and Nerve Block Studies on Spinal Tissues
4. Biomechanical Studies of Stress/Strain on the Spinal Tissues from Loading
To understand the basic mechanisms for somatic pain, a review of neuroanatomical studies is necessary. The presence of mechanosensitive receptors and afferents in this context establishes the framework to begin our discussion. Recent advances in immunohistochemistry techniques have allowed for histological visualization of mechanoreceptors and nociceptive afferents in the soft tissues of the spine. The presence of these afferent receptors and fibers is the starting point for action potential generation and intuitively are responsible for the symptomatic complaints that patients present with and the musculoskeletal structure and functional changes that accompany pain syndromes. Neurophysiologic studies have furthered the understanding of the relationships between electrical, chemical, and mechanical stimulation of the respective afferent units.

**Receptor & Fiber Classifications**

Based on the work of Polacek, Freeman and Wyke published their afferent terminal classification system in 1967 which is currently the most commonly used. Wyke characterized articular receptors from facet capsules into four categories determined by the individual morphological and behavioral characteristics of the receptor or ending (Table 1).

Because of confusion in the literature regarding differences in classification systems among receptors and nerve fibers, it is further necessary to expand upon the nerve fiber classifications to formulate a basis for further discussion. There are two classification systems for peripheral nerve fibers. The Erlanger-Gasser classification system uses capital letters (A, B, and C) to categorize both afferent and efferent fibers. Another system, the Lloyd-Hunt classification system uses Roman numerals (I-IV) as its designation. While this system was originally designed to classify muscle afferents only, enhancement in recording techniques have made it possible for sensory physiologists to subgroup nerve fibers, and thus it is used today.

Such mechanoreceptors through their respective afferents initiate sensory signals following stress and strain applied to the ligament during spine loading or motion that arrive at the spinal cord’s dorsal horn. These receptors have different sensitivities to loading depending on their composition and position. Each receptor/channel once stimulated above threshold opens allows Na+ to enter and the resulting depolarization can result in the generation of action potentials. The intensity of the stimulus can be encoded by the frequency of action potentials.

Afferent input from the periphery arrives in the dorsal horn of the spinal cord. Specifically, nociceptive afferent transmission enters the central nervous system at lamina II, while mechanoreceptive afferent transmission arrives at lamina VII. Acting upon substantia gelatinosa neurons through interneuronal connections nociception transcends contralaterally cephalad through the spinothalamic and spinoreticular tracts to respectively arrive at the thalamus and reticular formation where signals are processed and may ultimately transcend to the cortex depending upon its regulation for interpretation of pain. Mechanoreception, in contrast, transcends ipsilaterally cephalad via the dorsal columns to the cerebellum and other higher centers for proprioception. Simultaneously, via local reflex responses signaling the anterior primary motor neurons in the anterior horn of the spinal cord, neuromuscular reflexes are generated. Further, through interneuronal connections acting upon the intermediolateral cell column, pre-ganglionic sympathetic efferent stimulation is generated, more commonly referred to as somato-visceral reflexes.
Neuroanatomical Identification Spinal Somatic Afferents

Animal Studies

In reviewing more recent neuroanatomical studies in animals, encapsulated mechanoreceptive endings (Types I-III receptors), and non-encapsulated free nerve endings (Type IV receptors) have been found to be present within the soft tissues of the lumbar, thoracic, and cervical spine (including the intervertebral disc, zygapophyseal joint, anterior and posterior longitudinal ligaments, ligamentum flavum, interspinous and supraspinous ligament, and the deep musculature surrounding the posterior elements).\textsuperscript{24,25,55,56,74,77,115,117} which causes reflexogenic contraction of the paraspinal muscles to protect and possibly prevent ligamentous damage while at the same time maintaining stability through local reflexes.\textsuperscript{104} Similarly, afferent input acting through spinal pathways contributes to proprioception and suprasegmental motor control.\textsuperscript{113} Type IV afferent fibers (nociceptors) signal noxious stimulus through mechanical deformation, or by chemical depolarization and transmit information regarding tissue damage to higher centers where pain may be qualified and other physiological responses occur.\textsuperscript{85}

Human Studies

Recently, investigators have identified the presence of mechanoreceptors, nociceptors and their respective afferent fibers (units) in human spinal tissues, including the ligaments, facet joints, and intervertebral discs.\textsuperscript{34,39,54,56,69,70,91,106,108} In a histological analysis of normal human thoracic and lumbar facet capsules, McLain and Pickar,\textsuperscript{69} reported the presence of Types I-IV receptors and noted their presence to be a smaller proportion in comparison to that previously reported in the cervical spine. It is the connection of these receptors to respective afferent nerve fibers that provides the innervation of the lumbar spine. The dual nerve supply of the intervertebral disc via the sinuvertebral nerve and gray rami communicantes, and the branches of the dorsal rami are responsible for providing innervation of the soft tissues of the lumbar spine.\textsuperscript{14}

The Effects of Inflammation on Afferent Sensitivity

The effect of inflammation on the mechanosensitivity and discharge rates of afferent units has also been investigated by some of the above referenced researchers. Substance P and other neurotransmitters such as Calcitonin Gene Related Peptide (CGRP) that are released during nociceptive stimulation cause peripheral sensitization of the nociceptive fibers making them more susceptible to mechanical and chemical stimulation.\textsuperscript{118} In other work, Cavanaugh et al.\textsuperscript{22} injected carrageenan and kaolin, commonly used products that result in acute tissue inflammation with the release of histamine, bradykinin, and prostaglandins, into the extracellular tissue. They discovered in the presence of inflammation, elevated baseline discharge rates and there occurred vigorous multi-unit response to stretch by moving the facet joint approximately 1 mm in inferior-superior, anterior-posterior, and lateral-medial directions. This research, and other studies\textsuperscript{83,84} demonstrates that peripheral nerve endings become sensitized by chemical mediators released as part of the inflammatory cascade in the face of tissue damage.

Consequently, inflamed joints have been found to have an ongoing background nerve discharge that can cause constant pain at rest and sensitized nerve endings can cause increased pain during ordinary movements. Thus, afferents in the adjacent tissues that normally fire only when mechanical stress is clearly noxious, will fire at much lower stresses in the presence of inflammation, and can maintain a background discharge even without mechanical stress.\textsuperscript{23}
### Table 1.


<table>
<thead>
<tr>
<th>Type</th>
<th>Morphological Appearance</th>
<th>Average Dimensions</th>
<th>Location</th>
<th>Functional Characteristics</th>
<th>Other Terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Thinly encapsulated globular corpuscles usually found in clusters.</td>
<td>400-100µm long</td>
<td>Fibrous capsules of joints, and in periarticular ligaments and tendons; usually in the superficial layers</td>
<td>Static &amp; Dynamic Mechanoreceptors, low threshold, slowly adapting afferent ending.</td>
<td>Ruffini’s ending, Golgi-Mazzoni ending, Meissner’s corpuscle, basket or spray-type ending.</td>
</tr>
<tr>
<td>II</td>
<td>Thickly encapsulated conical or cylindrical corpuscles</td>
<td>250-300µm long &amp; 100µm wide</td>
<td>Fibrous capsules of joints in the deeper subsynovial layers, and at junctions of fibrous tissue and fat; often accompanied by vascular leash; oriented along with the connective tissue fibers</td>
<td>Dynamic Mechanoreceptors, low threshold, rapidly adapting afferent ending.</td>
<td>Pacinian corpuscle, Vater-Pacinian corpuscle; modified Pacinian corpuscle; Paciniform corpuscle; Meissner’s corpuscle; Golgi-Mazzoni body; bulbous corpuscle; club-like ending</td>
</tr>
<tr>
<td>III</td>
<td>Thinly encapsulated fusiform corpuscles</td>
<td>Up to 600µm long; 100µm long</td>
<td>Applied to surfaces of joint ligaments and tendons (Collateral &amp; intrinsic), as well as in dense fibrous connective tissues</td>
<td>Dynamic mechanoreceptors, high threshold, very slowly adapting afferent ending</td>
<td>Golgi’s ending, Golgi tendon organ, Golgi-Mazzoni corpuscle</td>
</tr>
<tr>
<td>IV</td>
<td>(a)Traditional plexuses of unmyelinated nerve fibers (b) Free unencapsulated, unmyelinated nerve endings</td>
<td>0.5-1.5 µm in diameter</td>
<td>(a) Fibrous capsules of joints. Adventitial sheaths of articular blood vessels (b) Joint ligaments (Collateral and Intrinsic)</td>
<td>Nociceptive mechanoreceptors; very high threshold, non-adapting afferent ending chemosensitive (to abnormal tissue metabolites); nociceptive receptors</td>
<td>Nociceptor, free nerve ending</td>
</tr>
</tbody>
</table>

Another clinical implication resulting from these studies demonstrates that inflammation resulting from damage to spinal structures associated with degeneration or capsule, ligament, disc, or muscle sprains or strains could cause prolonged nociceptor excitation. This may
contribute to a vicious cycle including muscle spasm and secondary hyperalgesia, that leads to persistent pain and perpetuated spinal joint dysfunction.\textsuperscript{23}

**Surgical Studies and Nerve Block Studies on Spinal Tissues**

Other areas of investigation have clinically identified the viscoelastic elements of somatic musculoskeletal soft tissues as being pain generators. In the spine, the medial branch of the dorsal primary rami has been identified as the innervating structure to the facet joints.\textsuperscript{16-18,31,96} Pain provocation studies and subsequent anesthesia including medial branch blocks have identified the facet joints to be significant pain generators involved in musculoskeletal pain.\textsuperscript{9,10,15,36,95-100} Provocation discography has also provided insight into the prevalence of discogenic pain and the underlying annular lesions structurally associated with this clinical spinal pain syndrome.\textsuperscript{13,20,68,71,78,79,93,94,109} These studies and others have identified the spinal joints as being a significant source of somatic (referred or scleratogenous) musculoskeletal pain,\textsuperscript{63} while the spinal nerve roots through compression or chemical radiculitis, have been identified as the major source of radicular pain.\textsuperscript{12,21,27,37,58-61,87,102,111}

**Posture**

To further explore the necessity of radiographic examination to determine clinically relevant articular alignment, a discussion of posture is necessary. Human posture may be defined as the position or carriage of the body as a whole having genetic, habitual, and injury influences. Posture literature has often held that the relationship of the line of gravity to the body has a functional significance to the musculoskeletal system since rotational (bending) moments are created if the line of gravity and the centers of weight-bearing joints do not coincide.\textsuperscript{90} While some have considered the relationship between posture and musculoskeletal pain controversial, the majority of studies have found a positive correlation between abnormal posture/ altered joint alignment and musculoskeletal pain (see Section X for a complete review of each region).\textsuperscript{30,52,107} Abnormal posture increases load on pain sensitive discoligamentous tissues causing extraneous efforts to be endured by the muscular stabilizing system of the spine.\textsuperscript{29} Increased muscular activity of the trunk muscles has been associated with back pain.\textsuperscript{8,26,49} Posture also has an effect on resultant spinal function including coupling patterns,\textsuperscript{28,85} and range of motion.\textsuperscript{32} Postural changes and sustained loading on the spinal joints have further been found to increase stress concentrations in the intervertebral discs,\textsuperscript{3,4,6} and posterior elements of the spine.\textsuperscript{5} Increased loading and spine injury have been found to be a precursor to spinal degeneration.\textsuperscript{2,43} This concept of abnormal posture, has led to a number of investigations to define normal posture.\textsuperscript{44,46,48,53}

Biomechanical principles (applying mechanics to a living organism) can be applied in the assessment of posture. A basic theorem in physics and engineering holds that the movement of any object can be decomposed into a rotation, translation, and deformation. Rotation can be defined as a circular movement in degrees, translation as a linear or straight-line movement, and deformation as a change in size or shape of an object. By the 1970s, researchers were using this fundamental engineering principle to describe the motion of spinal segments as rotations and translations in 6 degrees of freedom (DoF). The possible movements of a spinal segment are illustrated in Figure 2. These movements can be qualitatively classified as rotations (R) on each axis denoted with the listings of Rx, Ry, and Rz and translations (T) along each axis, listed as Tx, Ty, or Tz.\textsuperscript{112}
In the early 1980’s, Harrison applied the Cartesian coordinate system to upright posture in categorizing the possible permutations as combinations of the simple postural rotations (Rx, Ry, Rz) and translations (Tx, Ty, Tz) of the head (H), thoracic cage (TC), and pelvis (P). Breaking posture down into an assessment of rotations and translations of the head to thorax, thorax to pelvis, and pelvis to feet in 6 degrees of freedom (DoF) is Harrison’s original contribution to the knowledge base of postural assessment. As opposed to qualitative assessments describing a head tilt or a high shoulder, posture can be quantitatively described as measures of the rotations (Rx, Ry and/or Rz) (in units of degrees), and translations (Tx, Ty, and/or Tz) (in millimeters or centimeters) can be made. Combining single postures in combination provides possible upright human postures in static equilibrium.

To perform a postural analysis, anatomical landmarks are viewed visually, or marked on photographic images and digitized using computer software to quantify each posture from defined points. The suggested landmarks are medial and lateral maleolus, mid-knee, mid-lateral thigh, pubic symphysis, mid-ASIS in AP view, ziphoid, episternal notch, upper lip, glabella, EAM, the shoulder AC joint, medial elbow, hand, and posterior gluteus muscles. Using grid photography, a quantitative analysis of posture can be performed utilizing fixed reference points. In this manner, translational displacements can be measured in degrees and rotations can be measured in degrees to quantify postures of the head, thorax and pelvis. Postural analysis requires training and skill, as many postures present as combined postures of two or more main motions. For example, since the mass of the thoracic cage is large, as mentioned above, the anterior/posterior translations of the thoracic cage (±TzTC) not only will cause mid thorax to be displaced a perpendicular distance from a vertical line through mid-pelvis in the lateral view, but will also cause the opposite pelvic translation with concomitant pelvic tilt. Inasmuch, this may be cause for confusion when looking at a superior global body part without determining the position of the immediate inferior global part. Using a consistent postural assessment protocol, the global object being evaluated can be systematically compared to the global object below.

Certain postures require radiographic confirmation for differentiation. For instance, thoracic cage flexion/extension is more difficult to visualize, without checking vertical alignment.
of T1 and T12 on a lateral radiograph, and will also cause the opposite pelvic forward/backward translation concomitantly.\textsuperscript{47} Vertical translations of the thoracic cage ($\pm T_{YTC}$) are difficult to decipher without noting a straightening or hyper-lordosis of lumbar spine on a lateral radiograph. Extremity joint positions and anomalies can also be responsible for errors in postural analysis.

**Biomechanical Studies of Loading**

The correlation of visual postural analysis with radiographic images assists the clinician in identifying etiological and causative factors responsible for the patients presenting complaints; a necessary step in chiropractic differential diagnosis. Indeed, abnormal loads from abnormal posture has been found to be associated with soft tissue remodeling (Davis’ Law), and hard tissue (bony) remodeling (Wolff’s Law). For example, a number of studies have determined correlations between increased intervertebral disc loading and subsequent degeneration.\textsuperscript{6,47,51,62,65} Other studies have determined degenerative spinal changes in response to anular injury.\textsuperscript{7,80-82,103} Still other work has identified the progression of degeneration to osteophytes limiting mobility and function of musculoskeletal articulations.\textsuperscript{64,66,75,76,86,105} Figure 3 summarizes the biomechanical relationships between spinal subluxations and clinically relevant pain syndromes.

**Figure 3. Spinal Subluxations (over time) Cause Pathologies and Pain**

<table>
<thead>
<tr>
<th>Spinal Subluxations</th>
<th>Segmental R or T</th>
<th>Abnormal Posture</th>
<th>Sagittal Buckling</th>
<th>Euler Buckling</th>
<th>Segmental Instability</th>
<th>Scoliosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal Pathologies &amp; Pain</td>
<td>Systemic Pathologies &amp; Pain</td>
<td>Pain &amp; Spasms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Clinical Considerations of the Pain Patient & Radiological Necessity**

Observations made from the moment a patient enters the office can reveal much about their condition. Antalgic postures, altered gaits and guarded movements are examples of presentations that reveal important information. After reviewing the patient history, even more knowledge is gained. Does the patient have pain or paresthesia in a dermatomal distribution suggesting possible nerve root involvement? Conversely, does the patient have local or referred (scleratogenous) type pain possibly arising from somatic structures such as the disc, facet, ligament, muscle, or viscera? While a standard neurological examination may help to confirm the presence of nerve root involvement, the same examination is poor in discriminating patients with somatic pain. Even more complex are the uncertainties regarding psychosocial factors and patient motivations to consider when evaluating the pain patient. Within this context, this section will conclude with the necessity for radiographic evaluation in the musculoskeletal pain patient.

In recent years, there have been significant advances in the understanding of the physiologic and biochemical processes that are involved in pain processing at a spinal level. The elucidation of these multifaceted processes has meant a shift away from the conceptualization of pain as a simple “hard-wired” system with a pure “stimulus-response” relationship. In fact, many patients report pain in the absence of tissue damage or any likely pathophysiological cause, which may be due to psychosocial factors, or be related to plastic changes within the nervous system. The International Association for the Study of Pain defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage. Naturally, pain is subjective, and highly individualistic. Theorists view pain as not simply a sensation, but as a multidimensional phenomenon involving sensory, evaluative, emotional, and response components. Each person learns the meaning of the word, pain, through experiences related to injury in early life, and personal, social, and cultural influences all are thought to play important roles in the pain phenomenon. Because pain, particularly persistent pain, is not often directly tied to specific pathophysiology, but rather is linked to integrated perceptions arising from neurochemical and biomechanical input, cognition, and emotion, the mind greatly influences the intensity of the pain. Moreover, there is a poor association between objective measures of physical pathology and the amount of pain and disability that a patient may express. These factors must be taken into consideration in the realm of patient management.

Clinical decision-making is based upon securing a working diagnosis from a review of the patient history, physical examination, standard tests, and imaging studies. At the center of this mix, lays the patient and their complaints. Patient evaluations are not as simple as looking at test results. Comorbid factors such as patient motivation can further influence patient responses on a number of levels, from questionnaire responses to actual test performance. Patients have been known to amplify symptoms or functional status for a variety of reasons based in the human nature. Anxiety, stress, and emotional disturbances such as depression or hysteria may be responsible for elevated pain scores. In addition, the effects of compensation, litigation, and employment have been named as influences in patient status and outcome. It is clear that comorbid factors exist in patient status and recovery, thus, attentiveness in assessment of the big picture is important for clinicians to consider.

Recent models of spinal pain have been proposed to assist clinicians and researchers in developing useful evaluation and management protocols. Waddell conceptualized the back pain problem as possessing three distinct elements:
Pain: an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage;

Disability: diminished capacity for everyday activities and gainful employment; and

Impairment: an anatomical or physiological abnormality leading to loss of normal bodily ability.

While the three elements may be related, it is noteworthy that the strength of the relationship is not perfect and disassociation of the elements can occur.

Another model of disablement has been adapted to the physiotherapy management of low back pain. This model is slightly different to Waddell’s as it makes the distinction between a functional limitation and a disability.

Functional Limitations: restrictions in performance at the level of the individual (i.e., the ability to perform a task of daily living);

Disability: restrictions in the ability to perform socially defined roles and tasks expected of an individual (i.e., inability to work or participate in family social functions).

The distinction between functional limitations and disability helps explain why two patients with similar impairments and functional limitations may have very different levels of disability. In common, however, is the fact that clinicians must make decisions based on interpretation of a multitude of test results.

Four kinds of measurements provide relevant information about patient clinical status and/or response to treatment. In general, they are:

1. Perceptual measurements (i.e. reports of pain severity and pain tolerance),
2. Structural measurements (i.e. anomalies, pathology, spinal subluxation, and abnormal posture),
3. Functional measurements (i.e. range of motion, strength, stiffness, activities of daily living), and
4. Physiologic measurements (i.e. neurologic assessment, laboratory examinations) (Figure 2).

The most prevalent complaint among patients presenting to a chiropractic office is musculoskeletal pain. Thus, issues relevant to pain and patient motivations are noteworthy to understand the meaningfulness of spine instrument measures. Research aimed at assessing the quality and effectiveness of health care as measured by the attainment of a specified end result, or outcome is known as outcomes assessment. Such measures include parameters such as improved health, lowered morbidity or mortality, and improvement of abnormal states (perceptual, structural, functional, and/or physiological). Thus, radiographic analysis of possible structural spinal subluxations can be considered of paramount importance in the overall assessment of a presenting patient’s condition.
References


XIII. Legal Obligations of a DC for radiographic Use (Case Law, Judge’s decisions)

Introduction

As noted in Sections III and VI above, some DACBRs claim that Chiropractic Clinicians are over-exposing the public, taking unnecessary initial X-rays, criminal for taking any post X-rays, have no evidence-based support for subluxation assessment with spinal radiography, X-rays should only be recommended in “Red Flag” cases, and that X-rays are seldom useful in deriving the sequence of care that will be given to an individual patient. Having already addressed the science behind several of these claims, this section now explores whether there is legal authority in support of the DACBRs’ claim that X-rays should only be recommended in “Red Flag” cases. Additionally, the new CCGPP Guidelines do not support routine chiropractic radiographic evaluation, i.e., "x-rays for routine uncomplicated cases are not supported" (www.ccgpp.org).

While this panel is in agreement with the DACBRs that X-rays should be performed in so-called “Red Flag” cases, this panel does not believe that the use of X-rays should be limited or restricted only to those instances. An examination of the applicable statutes and case law concerning chiropractors and their use of X-rays reveals little, if any, support for the DACBRs’ and CCGPP’s position that chiropractors’ use of X-rays should be restricted to “Red Flag” cases.

The Majority of States Provide Diagnostic X-ray Privileges to Licensed Chiropractors

An overwhelming majority of states extend broad diagnostic X-ray privileges to licensed chiropractors by statute, either expressly or impliedly. Many states require their licensure examinations to test the applicants’ knowledge of X-ray diagnosis and technique. Furthermore, in several states the eligibility requirements for a license demand a minimum number of hours spent studying X-ray diagnosis and technique. Our brief search revealed that at least forty (40) states are characterized by one or more of the previous statements.

The majority of states generally define the scope of chiropractic care to include the use of X-rays for diagnostic purposes, either expressly or implied. Though the precise statutory language often differs there is remarkable consistency among the states to allow chiropractors the use of X-rays to diagnose patients. Sections of several statutes expressly and implied, allowing the use of X-rays are provided here to illustrate the point.

General Statutes of Connecticut, Section 20-28(b) – Any chiropractor who has complied with the provisions of this chapter may:

…

(2) Examine, analyze and diagnose the human living body and its diseases, and use for diagnostic purposes the X-ray or any other general method of examination for diagnosis and analysis taught in any school or college of chiropractic which has been recognized and approved by the State Board of Chiropractic Examiners;

Delaware Code, Title 24, §701(b) – The practice of chiropractic includes, but is not limited to, the diagnosing and locating of misaligned or displaced vertebrae (subluxation complex), using X-rays and other diagnostic test procedures. Practice of chiropractic includes the treatment
through manipulation/adjustment of the spine and other skeletal structures and the use of
diagnostic X-rays.

**Idaho Statutes, Title 54, Section 704 – CHIROPRACTIC PRACTICE.** Chiropractic
practice and procedures which may be employed by physicians are as follows:

(1) The system of specific adjustment or manipulation of the articulations and tissues of the
body; the investigation, examination and clinical diagnosis of conditions of the human body
and the treatment of the human body by the application of manipulative, manual, mechanical,
physiotherapeutic or clinical nutritional methods and may include the use of diagnostic X-
rays.

**Indiana Code, 25-10-1-1(1) – “Chiropractic” means the diagnosis and analysis of any
interference with normal nerve transmission and expression, the procedure preparatory to and
complementary to the correction thereof by an adjustment of the articulations of the vertebral
column, its immediate articulation, and includes other incidental means of adjustments of the
spinal column and the practice of drugless therapeutics. However, chiropractic does not include
any of the following:**

…

(F) the taking of X-rays of any organ other than the vertebral column and extremities;…

Despite the differences in language, notice that each of the above statutes allows licensed
chiropractors to perform X-rays for diagnostic purposes. The same is true for each of the forty
states reviewed by this panel. Indiana’s definition of “chiropractic” is included to illustrate how
some statutes imply that the use of diagnostic X-rays is within the scope of chiropractic care
without expressly stating as much. Here, Indiana expressly prohibits “the taking of X-rays of
any organ other than the vertebral column and extremities.” The statutory, and likely obvious,
implication is that X-rays of the vertebral column and extremities is permissible.5

Of greater significance is the absence in the statutes of additional guidelines, limitations,
or restrictions of chiropractors’ use of diagnostic X-rays.6 No statute reviewed by this panel sets
forth any criteria chiropractors should employ in determining whether X-ray diagnosis is
appropriate for a given patient in a given circumstance. No legislature has specified any
ailments or injuries for which diagnostic X-rays are required or prohibited. State legislatures
have effectively left the determination of when to use diagnostic X-rays in the discretion of the
individual chiropractors. This is in direct conflict with the restrictions suggested by DACBRs
and the CCGPP Guidelines.

**X-ray Diagnosis is Rarely Grounds for Disciplinary Action**

All of the states reviewed by this panel provide grounds for their respective board of
chiropractic examiners (board) to take disciplinary action against a chiropractic licensee.7. Those
disciplinary grounds are enumerated in the same statutes which create that state’s board,
establish the board’s rulemaking authority, and dictate the procedures the board must abide by.
By enumerating the disciplinary grounds in this way the legislatures of the individual states are
achieving two important functions. First, it provides the licensed chiropractor advance warning
of conduct which may precipitate disciplinary action. Second, it specifically limits the grounds
on which the board can take disciplinary action.
Below is a section of the Iowa statute as a brief example of enumerated grounds for
disciplinary action. There is a maxim of statutory interpretation which requires special mention
here; *expressio unius est exclusion alterius*. A loose translation of this phrase means roughly,
the expression of one at the exclusion of others. Under this maxim, where a statute specifies one
exception to a general rule or assumes to specify the effects of a certain provision, other
exceptions or effects are excluded⁸.

2005 Merged Iowa Code and Supplement, Title IV, §151.9 – Revocation or
suspension of license.
A entry to practice as a chiropractor may be revoked or suspended when the licensee is guilty of
the following acts or offenses:
1. Fraud in procuring a license.
2. Professional incompetency.
3. Knowingly making misleading, deceptive, untrue or fraudulent representations in the
practice of the licensee's profession or engaging in unethical conduct or practice harmful or
detrimental to the public. Proof of actual injury need not be established.
4. Habitual intoxication or addiction to the use of drugs.
5. Conviction of a felony related to the profession or occupation of the licensee or the
conviction of any felony that would affect the licensee's ability to practice as a professional
chiropractor. A copy of the record of conviction or plea of guilty shall be conclusive evidence.
6. Fraud in representations as to skill or ability.
7. Use of untruthful or improbable statements in advertisements.
8. Willful or repeated violations of the provisions of this Act.

Though enumerating fewer grounds for disciplinary action than many states, the content
of the Iowa statute above is common to most states. Note the absence of any provision allowing
the board to take disciplinary action for a chiropractor’s performing or failing to perform
diagnostic X-rays. Applying the maxim of *expressio unius est exclusion alterius*, it is clear that
neither the performance of diagnostic X-rays nor the lack thereof are grounds for disciplinary
action. This is also common to a majority of states, with the exceptions of Colorado and Oregon
which expressly mention “X-ray” in their disciplinary statutes. The relevant portions of the
Colorado and Oregon statutes are as follows:

**Colorado Revised Statutes, §12-33-117(1)** - Upon any of the following grounds, the board
may issue a letter of admonition to a licensee or may revoke, suspend, deny, refuse to renew, or
impose conditions on such licensee's license:

(v) Engaging in any of the following activities and practices: Willful and repeated ordering or
performance, without clinical justification, of demonstrably unnecessary laboratory tests or
studies; the administration, without clinical justification, of treatment which is demonstrably
unnecessary; the failure to obtain consultations or perform referrals when failing to do so is not
consistent with the standard of care for the profession; or ordering or performing, without clinical
justification, any service, X-ray, or treatment which is contrary to recognized standards of the
practice of chiropractic as interpreted by the board;

**Oregon Revised Statutes, §684-100(1)** – The State Board of Chiropractic Examiners may
refuse to grant a license to any applicant or may discipline a person upon any of the following
grounds:
(B) Willful ordering or performance of unnecessary laboratory tests or studies; administration of unnecessary treatment; failure to obtain consultations or perform referrals when failing to do so is not consistent with the standard of care; or otherwise ordering or performing any chiropractic service, X-ray or treatment that is contrary to recognized standards of practice of the chiropractic profession.

The Colorado and Oregon statutes impose disciplinary action for “performing X-rays where contrary to recognized standards of the practice of chiropractic” as interpreted by either the board or the profession, respectively. These two statutes begin to point to the crux of the matter at hand, as well as the further unraveling of any legal support for the DACBRs and the CCGPP Guidelines to restrict the use of X-ray diagnosis to “Red Flags.”

In addition to the “recognized standards of the practice of chiropractic” mentioned in the Colorado and Oregon statutes, nearly every other state imposes disciplinary action for “unethical conduct,” “unprofessional conduct,” or for falling below the “reasonable standard of care” for chiropractors. Though most states fail to explicitly mention X-rays in their grounds for disciplinary action, it is a safe assumption that X-ray diagnosis or a lack thereof may be considered unethical, unprofessional, or falling below the standard of care under certain circumstances.

The question now becomes “under what circumstances?” Referring to the statutes provides no assistance in attempts to answer this question. Not being chiropractors, legislators deliberately draft such legislation to be open-ended so as to ensure general applicability. They are reluctant to establish highly specific or rigid standards, preferring instead that the determination of unprofessional or unethical conduct be done on a case-by-case basis. Legislators understand that each patient and situation is different and that “one-size-fits-all” is not a workable standard. Therefore, one must examine the relevant case law (jury verdicts and judicial rulings) to see whether clear and consistent standards have been developed.

A Survey of Relevant Case Law Provides No Clear Standards, and Therefore Does Not Support Limiting Diagnostic X-rays to “Red Flags”

As noted above, whether specific conduct is “unethical,” “unprofessional,” “contrary to recognized standards”, or below the “standard of care” is determined on a case-by-case basis. The particular circumstances surrounding each case are rarely identical, if ever. Thus, conduct deemed unethical or unprofessional in one situation may be appropriate, justified, or at least understood in another.

Generally speaking, the case-by-case analysis is only performed because the parties to a dispute failed to reach a settlement and opted to go to trial. A judge or jury often determines the nature of the chiropractor’s conduct based on the credibility and rationale expressed by one or more expert witnesses. The following from *Ford v. Peters*, 2005 U.S. Dist. LEXIS 9262, 19-20, provides a superb explanation of this phenomenon;

“Most courts...hold that the duties of chiropractors to their patients...include: (1) a duty to exercise reasonable care in the diagnosis and treatment of their patients, including reasonable care in determining whether chiropractic treatment is appropriate in a particular situation...

Further, in most of these jurisdictions, the standard of care is generally defined with its
scope determined by expert testimony as to the standard of care appropriate under the circumstances.”

This panel conducted a thorough search of federal and state cases involving chiropractors and their standard of care applicable to both the use and lack of use of diagnostic X-rays. Upon completing this search the panel concludes that the relevant case law yields no uniform standards which suggest chiropractors should limit their use of diagnostic X-rays to “Red Flag” cases.

There are three primary findings which undercut the existence of a uniform standard. The first is the sheer lack of authoritative cases. Very few cases exist which have directly at issue a chiropractor’s performing or failing to perform X-rays. One can speculate wildly about the reasons for the absence of such cases. Perhaps patients rarely have complaints about their chiropractor’s use of X-rays. Of those that do complain, it is possible a settlement is reached or the patient is satisfied with any disciplinary action taken by the board and decides not to pursue it any further. Among the cases that do make it to trial, few appeals are taken beyond a state circuit court. A decision by the Court of Appeals of Louisiana, Second Circuit has no authority over out-of-state courts, and only persuasive authority among the other circuit courts of Louisiana.

Second, there is little or no consistency between the verdicts and judicial rulings of the few relevant cases. The following case reviews will demonstrate this lack of consistency.

a. \textit{Thomas v. Farris}, 175 S.W.3d 896; 2005 Tex. App. LEXIS 8798 (2005). - The patient was involved in an automobile accident, after which she consulted the chiropractor for treatment. Thereafter, she fell and developed severe hip pain. She ultimately had a total replacement of her left hip. The patient and her husband brought an action against the chiropractor and claimed he was negligent in failing to x-ray the patient's hips and discover fractures incurred after the accident. The trial court granted the chiropractor summary judgment and the court affirmed on appeal. One witness testified that, in his opinion, the chiropractor should have taken x-rays of the patient's hips, but the witness provided no testimony that, if such conduct of the chiropractor was a violation of the standard of care for chiropractors, it caused or exacerbated the patient's hip fractures. There was no testimony that the patient's failure to stay off her leg caused further injury. Because there was no material fact issue raised by the evidence that the chiropractor's actions or omissions was a proximate cause of the patient's injuries, summary judgment in the chiropractor's favor was proper. The court of appeals affirmed.

b. \textit{Goodman v. Holder}, 8 Pa. D. & C.\textsuperscript{4}th 261; 1990 Pa. D. & C. LEXIS 384 (1990). - The patient was in an automobile accident in which she sustained a fractured sternum, multiple cuts and bruises, a fracture of the left elbow and shoulder and spondylolisthesis at L5-S1. The chiropractor treated the patient on numerous occasions. The patient alleged that during the period of treatment, the chiropractor never prescribed X-rays for her, which would have revealed the fracture to the sternum, left elbow, and shoulder. She further alleged that chiropractor never obtained a complete medical history. The patient's main contention was that the chiropractor's conduct amounted to both a breach of chiropractic standard of care and a breach of the normal standards of care in the community. The chiropractor's objection lay solely with the sufficiency of facts set forth and whether the facts presented an issue of punitive damages that should go to the jury. The court held that the failure of the chiropractor to take x-rays constituted negligence
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and that the patient alleged facts sufficient to constitute a possible claim for punitive
damages. Also, the court held that chiropractic standards were to be applied in the same
manner that standards for physicians were applied. The court denied the chiropractor's
preliminary objections in the nature of a demurrer.

a 63-year-old woman who sought chiropractic treatment following a stroke. The
chiropractor took a medical history and x-rays of her spine, which revealed diffuse
osteoporosis. During a manipulation of the patient's spine, which involved pushing on her
crossed arms, one of her arms was fractured. The trial judge rejected the deposition
testimony of the patient's expert witness who testified that in light of the patient's medical
condition, x-rays of the arm and shoulder area should have been taken since those parts
were affected by the stroke. The trial judge adopted the opinion of the chiropractor's
expert who testified that the chiropractor was not negligent in failing to x-ray the patient's
arm and shoulder because he was not adjusting or manipulating that area. The court held
that it would not disturb the findings of the trial court absent clear error, and that based
on the record, the trial court was not manifestly erroneous in accepting the testimony of
the chiropractor's expert. The court further held that the doctrine of res ipsa loquitur was
not applicable, but if it had been, the chiropractor sufficiently rebutted the inference of
negligence. The court of appeals affirmed the judgment of the trial court.

- The patient alleged that the chiropractor negligently failed to take x-rays of the patient's
shoulder, which was broken and dislocated, and to refer the patient to a medical doctor. A
jury returned a verdict for the patient, and the court affirmed. The court found no abuse
of the trial court's discretion in allowing plaintiff's counsel to inquire on voir dire if the
prospective jurors had any interest in the chiropractor's insurance carrier. Similarly, there
was no abuse of the trial court's discretion when it refused to allow a purported
"impeachment" witness to testify. The court found that the trial court acted within its
authority under *Colo. R. Civ. P. 16(d)(3)* in refusing to allow a witness to testify when the
chiropractor knew of the witness but failed to include the witness's name on a witness list
pursuant to a pre-trial order. The trial court properly admitted testimony on the
chiropractic oath since that evidence had probative value upon the issue of the standard
of conduct agreed to by all chiropractors in Colorado. Finally, the court concluded that
the instructions given to the jury properly identified the material questions of fact in
controversy and stated the law. The trial court's judgment for the patient was affirmed.

allegation that Beno provided services which were not authorized within the scope of
chiropractic practice. The court noted that under § 16401(1)(b)(iii), the practice of
chiropractic includes, “...the use of x-ray machines in the examination of patients for
the purpose of locating spinal subluxations or misaligned vertebrae of the human spine.”
Furthermore, the court held that “Rather than authorizing general diagnostic techniques,
the statute limited chiropractors to those methods which might reveal the existence of
misaligned or displaced vertebrae.”

patient alleged that the chiropractor was negligent for failing to detect and inform the
patient of an abnormal mass revealed on an x-ray. The court held that, “Although
chiropractors may take and analyze x-rays, they may only do so for diagnostic or
analytical purposes in the practice of chiropractic.” The purpose of such an examination, under Wis. Adm. Code Section Chir 4.03 includes "determination of the existence of spinal subluxations...."

Much of this inconsistency in the case law is due to the third finding which undercuts the existence of a uniform standard, which is the “battle of the experts.”

The “battle of the experts” is an unfortunate consequence of the situation described in Ford v. Peters. The adversarial nature of a trial combines with the need to establish whether a chiropractor’s conduct was reasonable under the circumstances to create confusion among judges and juries. At times, the “battle of the experts” results in the complete absence of any standard as demonstrated in Tilden v. Board of Chiropractic Examiners, which stated, “If reasonable chiropractors could differ, then the failure to perform the procedures is not necessarily evidence that the petitioner acted outside an acceptable range of care.” 135 Ore. App. 276; 898 P.2d 219; 1995 Ore. App. LEXIS 958.

Along this line, in discussing the French Society of Orthopaedic and Osteopathic Manual Medicine radiography guidelines, Maigne9 stated, “past verdicts and settlements have shown that in cases of post-manipulation complications, the absence of X-rays prior to manipulation is regarded, by the experts, as failure to conform to the standard of care (malpractice), even if prior X-rays could not, under any circumstances, have prevented the occurrence of the complications.” Therefore, it may be wise to obtain initial spinal radiographs of the intended spinal region where treatment is to be directed; this may avoid the hypocrisy of the ‘battle of the experts’ circumstance.

The “respectable minority doctrine.” The most common legal definition of standard of care is how similarly qualified practitioners would have managed the patient's care under the same or similar circumstances. This is not simply what the majority of practitioners would have done. The courts recognize the respectable minority rule. A number of states recognize it as a malpractice defense that the defendant acted in accordance with the custom of at least a "respectable minority," or recognized subgroup, of the relevant profession, even though his or her actions were at odds with mainstream professional practice.10

Conclusions

1. Chiropractors are authorized to employ spinal x-ray examinations in all 50 states of the U.S.
2. Statutes, rules and regulations concerning the practice of chiropractic do not explicitly limit the use of x-ray examinations to cases where “red flags” are present.
3. Some courts have explicitly upheld the use of chiropractic x-rays to detect or determine the presence of spinal subluxations.
4. Courts generally recognize that standard of care may be established under the respectable minority rule.


4. Whether the scope of chiropractic care in the remaining ten (10) states precludes the use of diagnostic X-rays or lacks similar testing and educational requirements is unknown to the panel at this time, as access to those states’ statutes was not readily accessible. However, this panel is confident that upon reviewing the applicable statutes of those remaining states that few, if any, would fail to include the use of diagnostic X-rays in the scope of chiropractic care. Not a single state’s statutes this panel reviewed failed to include diagnostic x-rays in the scope if chiropractic care, either expressly or impliedly.

5. Expressio unius est exclusion alterius is a maxim of statutory interpretation meaning that the expression of one thing is the exclusion of another. Under this maxim, if a statute specifies one exception to a general rule or assumes to specify the effects of a certain provision, other exceptions or effects are excluded.

6. Some states statutorily limit or prohibit the use of X-ray treatment or X-ray therapy. However, no state statute reviewed by this panel imposed limitations or an outright prohibition on the use of X-rays for diagnostic purposes.


XIV. Summary

These Radiographic Protocols/Guidelines were written by practicing chiropractors, who have noticed that other more restrictive radiographic protocols are/were written either by Managed Care Organizations (MCOs) to cut costs and maximize profits, by IME doctors working for MCOs, or by Academics with links to/or MCOs. Neither MCOs nor their paid IMEs have a place in the writing of clinical guidelines whether these are “Best Practices” or “Radiographic Practices” since these organizations/individuals have a potential financial conflict of interest that most often conflicts with the needs of the patient seeking healthcare.

Previous Radiographic Guidelines have often cited medical research that does not fit Chiropractic practice. Radiographic usage in the pharmacological and physical therapy (general exercise, ultrasound and other modalities) treatments of patients has no bearing on the radiographic needs of a practicing chiropractor, who is applying physical forces to patients’ spines via manipulation, adjustment, and rehabilitation forces in exercises and traction procedures.

This document, written by Practicing Clinicians, presents evidence supporting routine radiographic examinations of children and adults seeking chiropractic care for the biomechanical evaluation of spinal subluxation. Critics of routine radiographic utilization in Chiropractic practice often claim (Level V evidence) that there is no supporting evidence for biomechanical assessment of the spine. However, contrary to their ‘expert opinions’, there are approximately 1500 references of Class I-V (Levels I-IV of clinical research), reliability studies, validity studies, and/or biomechanical studies cited as the evidence in these Guidelines. The evidence is overwhelmingly in favor of routine radiographic utilization in clinical Chiropractic practice.

Since this Guideline document is over 380 pages, we present a very short summary of each section (I-XIII) for the interested reader who does not have the time to study each page.

Preface & General Radiography Summary

Any Guidelines that are “evidenced-based”, especially Radiographic Guidelines for Practicing Chiropractors, must not replace the clinical decisions of the healthcare provider, nor apply general rules to individual patients, who may not benefit from these average rules. In fact, the “father of Evidence-based Medicine” (EBM), Sackett, stated that EBM is clinical decision-making based on (a) sound external research evidence, (b) the individual healthcare provider’s clinical experience, and (c) the needs of the individual patient. MCOs often remove the individual healthcare provider’s clinical experience and the needs of the individual patient from their guidelines in order to minimize costs and increase profits.

It is assumed in these Radiographic Guidelines that the Chiropractor has studied x-ray physics, x-ray positioning, radiographic safety, x-ray diagnosis, and x-ray geometric line drawing methods, but a few expectations of basic radiographic usage are listed. The healthcare provider is expected to be performing these items without statements referring to these items in the rest of this document.

Section I. Description of Levels of Evidence

When considering “Evidence-Based Practice” (EBP), one of the immediate questions should be “what does and does not provide evidence?” MCOs and/or their paid IMEs often
restrict “their” evidence to randomized clinical control trials (RCTs). This often severely limits
the evidence to be considered because there are many more published cohort, cases series, and
case studies than there are published RCTs. Sackett, the father of EBM and EBP, suggested
using all available evidence, but by rating evidence levels (i.e., RCTs are rated higher than Case
Studies). Along these lines, the US Department of Health and Human Services
(http://www.ahrq.gov/) listed four levels of evidence:

- **Level 1.** Randomized controlled trials—including quasi-randomized processes such as alternate
  allocation.
- **Level 2.** Non-randomized controlled trial—a prospective (pre-planned) study, with predetermined
  eligibility criteria and outcome measures.
- **Level 3.** Observational studies with controls—including retrospective, interrupted time series (a
  change in trend attributable to the intervention), case-control studies, cohort studies with controls,
  and health services research that includes adjustment for likely confounding variables.
- **Level 4.** Observational studies without controls (e.g., cohort studies without controls, case series
  without controls, and case studies without controls)

Some documents rating evidence will include “Level V” as “Expert Opinion” and in fact
as the lowest level of evidence. In this document we have included this “Expert Opinion” level
of evidence as Level V. In this document we use Class I-V for Levels I-V because we added
some basic science, reliability, and validity studies as Class 1-4. Clinical studies are rated as
capitol letters A-D while basic science, reliability, validity studies, etc… are rated as lower case
letters a-d. The rating A or a is the highest while D or d is the lowest.

However, the reader should be wary of any Protocols/Guidelines that eliminate any of the
above levels of evidence (i.e., http://ccgpp.org), as there is usually a preconceived reason
(agenda) for eliminating any levels of evidence. This is especially the situation in the
Chiropractic literature evidence, where few RCTs have ever been published, but where a vast
number of Case Studies have been published.

### Section II. Chiropractic Guideline for Spine Radiography for the Assessment of Spinal
Subluxation in Children and Adults

A list of 27 “Indications” for spine radiographic (termed Spinography) examinations is
presented, which include any axial pain, any restricted range of motion, any head aches, any
trauma, any radiating pain, any abnormal posture, any spinal deformity, etc.

A minimum radiographic evaluation of the spine is defined and some general and specific
evaluations on these radiographic views are suggested. Additional radiographic views for trauma
cases are recommended, as are post-radiographic examinations to monitor patient progress.

Computer assisted radiographic analysis and motion radiography are deemed reliable and valid
for spine analysis.

### Section III. Background

Chiropractors, in English speaking countries, enjoy radiographic privileges due to their
education in all aspects of radiography but also in part to the history of utilization of spine
radiography by early Chiropractic pioneers.
A publishing subgroup of the Diplomats of the American Board of Chiropractic Roentgenology (DACBRs) and a few chiropractic academics have attempted to reduce x-ray privileges for practicing Chiropractic Clinicians. These suggested reductions in x-ray privileges by the subgroup of DACBRs and academics have come in the form of “expert opinion” chapters in various chiropractic texts, articles published in Index Medicus journals (JMPT, Chiropractic & Osteopathy), CINAHL and Mantis Indexes.

Relying on selective literature citations and Clinical Class V (expert opinion) evidence instead of all the available data, these DACBR and academic “expert opinions” have claimed a series of positions that have been shown to be false. These include:

- Normal spinal position does not exist,
- Acute muscle spasms cause cervical and lumbar kyphosis or hypo-lordosis,
- Normal spinal anatomic variants cause the spine to appear to be subluxated,
- X-rays should not be taken for biomechanical, screening, and
- Follow-up treatment x-rays are not warranted,
- Radiographic line analysis of spinal displacements is unreliable,
- X-ray positioning of patients is unreliable,
- X-ray analysis lacks predictive validity and biologic plausibility, and
- X-ray use to dictate treatment does not yield improved patient outcomes.

Additionally, this subgroup of DACBRs has been suggesting that Chiropractic X-ray privileges be confined to “Red Flag” cases only (i.e., fracture, infection, ruptured discs, tumors, etc.). Problematically, managed care organizations (MCO’s) use the DACBR “Red Flag” documents to enforce their mandatory reduction in radiographic utilization rates of practicing chiropractic clinicians. In fact, there is no evidence that these policies actually benefit the patient; but there is evidence that this increases the profits of MCO’s and insurance providers. Thus, it becomes clear that current attempts to limit radiography utilization rates of chiropractic clinicians is motivated more by profits and less by what is best for the patient.

Most of the “evidence”, that is not personal opinion, cited by this subgroup of DACBRs and MCOs are medical studies, which applied drug therapy as the treatment. Since studies using pharmacological treatments (“chemical” treatment) do not apply to the needs in Chiropractic care, where “physical” forces are being applied to patients’ spines, chiropractic radiographic utilization cannot be inferred from medical studies.

Section IV. Historical & Current Perspective

Historically, radiographic spinal analysis has been an integral part of a Chiropractic evaluation. The use of x-ray for clinical decision making dates back to BJ Palmer in 1910. Many Chiropractic Techniques were originated that used x-ray to determine subluxation listings. These include, but are not limited to, HIO, Wernsing’s Atlas Specific, Grostic, Gonstead, Diversified, Zimmerman’s Specific Adjusting, Logan Basic, Mears, Atlas Orthogonal, Life Cervical, Pettibon, CBP, Blair, Pierce-Stillwagon, Toftnes, Barge’s Tortipelvis and Torticollis, Orthospinology, and NUCCA.

Initial radiographs are a mandatory necessity in some of the chiropractic techniques practiced by the majority of chiropractors. This is evident by the National Board of Chiropractic Examiners’ surveys on utilization of techniques in the past few years. It is known from theses surveys that Gonstead, HIO, Logan Basic, and Pierce-Stillwagon are four of the most prevalent
chiropractic techniques and radiographic analysis is a necessity in these techniques. Thus, taking initial x-rays for biomechanical assessment of subluxation is the Standard of Care in Practicing Chiropractic offices.

Many professional surveys have been published on the utilization rates of Spinography by practicing Chiropractors. An increased utilization rate of spinal radiography by Chiropractors has been found through these surveys and is likely a result of different philosophies, analysis, treatment approaches, and treatment outcomes inherent in Chiropractic. Because a majority of Chiropractors utilize radiographic analysis for biomechanical evaluation of the patient’s structural spinal position/abnormality (subluxation defined in Section V), the use of initial x-rays for biomechanical evaluation of the spine can be considered part of the standard of practice for clinical chiropractic. Also, at least 20% of some surveyed Chiropractors indicated that they utilized full spine radiography on their patients.

Section V. Definition of Subluxation and Average Normal Spinal Alignment

Historically, there have been many different definitions of vertebral subluxation used by chiropractors and other health care providers. However, a commonality of many chiropractic definitions has been: 1) vertebral misalignment and 2) disturbance of normal nerve function. In general, chiropractors have long been displeased with the medical profession’s definition of subluxation, which usually has had something to do with translations of single vertebra beyond the limits of the spinal ligaments: i.e., retrolisthesis, laterolisthesis, and thin discs.

In general terms, instead of a precise definition of subluxation, chiropractors have resorted to vague terms such as “biomechanical aberration” and “loss of mechanical integrity of the spine” and have attempted to describe the effects of subluxation, such as “histopathology, kinesiopathology, pathophysiology, neuropathophysiology, and myopathology.” Often these definitions of subluxation are proposed by political organizations by consensus, instead of by scientific reasoning.

Harsh critics of the usage of the term/entity of subluxation often use cross-sectional studies, instead of longitudinal studies, to try to discredit the use of spinal subluxation in chiropractic terminology. Most symptoms and pathologies take time to develop and take time to resolve. Additionally, these critics of spinal subluxation utilize studies in which the only “adjustment” was a gross spinal manipulation without regard to pre-alignment and post-alignment of the subjects’ spines.

It is the opinion of this panel that practicing Chiropractors have defined subluxation, used it daily in their assessments, in their corrective adjustments and rehabilitative procedures, and in their explanations to patients since 1910. Any definition of subluxation should include the historical concepts used by Chiropractic Clinicians, should be consistent with mathematics and mechanical engineering principles, and it should be valid in terms of the known spinal sciences.

It is the consensus of this panel that the original definition of subluxation derived from the Palmers, “a bone that has lost its normal juxtaposition causing nerve interference”, is what Chiropractic Clinicians have used daily for approximately 100 years.

Most health care providers accept the average values as “Normal” from a plethora of physiologic, anatomic, and biomechanical measurements (such as normal blood pressure is 120/80). Similarly, average values as “Normal” from healthy subjects for spinal alignment have been determined and published in the scientific literature. Because an average normal spinal model for each region (cervical spine, thoracic sine, and lumbar spine) was not published until
recently, the Chiropractic founding fathers did not have access to any such normal values of segmental and/or global alignment. Thus they had only their intuition to guide them. However, this information is available to us at the present time.

From 1996-2003, normal spinal models were published for each region of the spine. These normal spinal models are of two types, average and ideal. These models have been criticized by persons denying the very existence of subluxation, and have been suggested to be solely ideal or theoretical in character without clinical utility. However, average normal spinal models have been developed and published in scientific journals.

In the AP/PA view, the spine should be vertical and all end plate lines should be horizontal including occiput, C1-C7, T1-T12, L1-L5, sacral base, and a line at the tops of the femur heads. These lines are the Gonstead Technique wedge lines or also they are the endplate lines from which perpendiculrars are drawn in the Cobb analysis, i.e., all wedge lines are parallel and all Cobb angles are 0° in the AP or PA spinal radiographic view. Another way to express this AP vertical alignment of the vertebrae is to state that all centers of mass are vertically aligned. In the cervical spine, this is equivalent in stating that the upper angle, lower angle, and CD angle on the nasium view are 90°, 90°, and 0°, respectively. In the thoracic and lumbar spines, this is equivalent in stating that all AP Risser-Ferguson angles are zero.

In the sagittal view, average normal rotation angles of each motor unit (two adjacent vertebrae) can be derived from drawing lines along the posterior body margins of every vertebra and measuring the angle of intersection of each pair. In actuality, these lines represent the slopes in an Engineering analysis of structures taught in Mechanics of Materials. For C1, the sacral base (S1), and the pelvic tilt, lines through these structures are often compared to a horizontal line for an angle of inclination in degrees. Segmental angles formed at adjacent vertebrae are termed Relative Rotation Angles (RRAs), while global angles (Absolute Rotation Angles are termed ARAs) in each region can be formed by comparing a superior vertebra in a sagittal region to an inferior vertebra. In this way an evaluation of the cervical lordosis (ARA C2-C7), thoracic kyphosis (ARA T1-T12 or ARA T2-T11), and lumbar lordosis (ARA L1-L5) can be measured in degrees. These x-ray mensuration methods have been shown to be highly reliable in numerous reliability studies.

There are 6 types of subluxation defined in this document, and these are mechanical descriptions for the allowable spinal displacements that can occur. Using the average normal spinal model, inside normal upright stance, that we precisely defined, these 6 types of displacements can be quantified.

1. **Segmental subluxations**: These are the segmental displacements from C1-S1 measured from the vertebra above relative to an origin located in the vertebra immediately below. These vertebral spinal subluxations are listed in terms of Rx, Ry, Rz, Tx, Ty, Tz).

2. **Postural main motion and coupled motion**: Postural displacements found in neutral resting stance are completely described as rotations and translation displacements of the head, thoracic cage, and pelvis. The majority of these displacements are concomitantly associated with spinal coupling/displacement patterns. Each postural displacement has a unique spinal displacement pattern that is normally associated with it.

3. **Snap-through buckling in the sagittal plane**: The alterations in the regional sagittal curves of cervical or lumbar lordosis to kyphosis and “S”-curves and, to some extent, changes in thoracic kyphosis to hypo-or hyper-kyphosis have been found to be consistent with the engineering Snap-through type of buckling.
4. **Euler buckling in AP/PA view**: This type of structural displacement is generally where the structures of the lower most segments in a spinal region experience some failure, e.g., axial rotation and/or lateral flexion of L4 & L5. These displacements are generally localized to the distal spinal regions of the cervical, thoraco-lumbar, and lumbo-pelvic and are generally associated with sub-catastrophic (non-complete tears) and sometimes catastrophic (macro) tears in the surrounding ligaments.

5. **Scoliosis**: Recently the non-neurogenic forms of scoliosis have been shown to be caused by a ‘slow-loading’ buckling mechanism. There are multiple different types, locations and complexities of scoliosis.

6. **Static or dynamic segmental instability**: These are the segmental displacements depicted in Figure 3 but are at the limit of or outside of the range of motion for the functional spinal unit. These are associated with significant ligamentous trauma.

An important topic when discussing our average spinal models’ application to the human population is a consideration of anatomical variations in a given persons spinal anatomy. There are several known anatomical variants of human spinal anatomy that affect spinal alignment/geometry, however, there are several variants that do not. Significant progress has been made in understanding the correlations between a variety of anatomical variants and spine geometric alterations; Chiropractic clinicians and researchers have played a significant role in this area of investigation.

**Section VI. Review of X-ray Usage and Guidelines by Orthopedic Surgeons, Family Practice Physicians, American Chiropractic College of Radiology (ACCR), and Medical Radiologists (ACR).**

There are several health care provider organizations that have radiographic privileges, and who have published information on radiographic utilization and protocols of radiographic procedures:

1. American College of Chiropractic Radiologists (ACCR),
2. Chiropractic College of Radiologists of Canada (CCRC),
3. American Academy of Family Physicians (AAFP),
4. American Medical Association (AMA),
5. American Academy of Orthopedic Surgeons (AAOS),
6. American College of Radiologists (ACR),
7. U.S. Agency for Health Care Policy and Research (AHCPR) Guidelines,
8. Danish Institute for Health Technology Assessment (DIHTA),
9. Royal College of General Practitioners (RCGP) Acute Low Back Pain Guidelines,
10. The Reed Group Neck Pain Guidelines (RGNPG),
12. Council on Chiropractic Practice Clinical Practice Guidelines (CCPCPG),

Approximately 50% of these Guidelines are reasonable for “routine radiographic utilization” for the initial evaluation of subluxation. However, one of these (CCRC) is totally different from the rest. The most reasonable Guidelines (any pain, any trauma to the spine, any
headaches, and any decreased range of motion) are provided by ACR, which is comprised of approximately 30,000 medical radiologists. ACR can be considered as the largest group of radiologists in the world and perhaps one of the most respected groups. Our PCCR Guidelines mirror the ACR Guidelines in many ways.

Section VII. Radiation Safety: LNT Model versus the Radiation Hormesis Model

The purpose of this section is to correct the general public’s false impression of the risks of medical/chiropractic x-rays. There are two models of radiation effects on organisms: Linear No-Threshold (LNT) model and the Radiation Hormesis model. Using the huge exposures during the atomic bombing of Japan in the 1940’s, the LNT model was derived by drawing a straight line down to zero exposure and claiming all radiation exposure causes a cancer risk. The LNT model continues to be used to estimate cancer risks from low doses of radiation, such as medical x-rays, without any supporting data. Proponents of the LNT model always omit any Radiation Hormesis information from their commentaries, review articles, and government documents.

There exists incontrovertible evidence that Radiation Hormesis (health benefit) occurs in plants, microorganisms, invertebrates, and experimental animals. In fact, it was proven with statistically significant results from countless studies that benefits from low levels of radiation improved physiologic function from immunity and reproduction to growth and longevity. Ironically, much of this research came from studies evaluating ‘risks’ from radiation – so author bias was not possible.

In this section, both the LNT model and the Radiation Hormesis model are reviewed. This review indicates that the risks from medical/chiropractic x-rays are likely zero and there are possible health benefits from such small exposures. Therefore, the conclusion is: the benefits from spinal x-rays outweigh the potential risks, because the risks are likely zero. In fact few people are aware of natural radiation exposure and the relative risks associated with daily living, which when compared to exposure from medical x-rays, are in the same range.

Section VIII. Reliability of Geometric Line Drawing Radiographic Analysis

Contrary to the Level V evidence espoused by a subgroup of DACBRs and Chiropractic Academics, there are more than 150 publications on spinal radiographic geometric line drawing methods. The overwhelmingly majority of these studies report that geometric line drawing on radiographs is highly reliable (in the good to excellent range) and has small standard errors of measurement and differences between/within observers. The sheer number of these studies makes geometric line drawing on radiographs one of the most studied topics in the peer-reviewed literature. Approximately 150 radiographic line drawing reliability studies are reviewed in 12 tables of different regions.

Section IX. Reliability/Repeatability of Radiographic Positioning

Contrary to the Level V evidence espoused by a subgroup of DACBRs and Chiropractic Academics, there are more than 55 publications on the test re-test reliability of radiographic positioning for spinal alignment. These studies come from Medical Doctors, Chiropractors, and Orthodontists. Tables of different regions are presented with reviews of approximately 60
publications on the reliability of radiographic positioning. The overwhelming majority of the studies report that radiographic positioning is highly repeatable.

**Section X. Description, Reliability, Validity & Efficacy of Common Chiropractic Radiographic Views**

There are numerous spine radiographic views that are utilized by both Medical Doctors and Chiropractors. There are additional radiographic views that are unique to the medical profession for locating pathologies and fractures. Additionally, there are some radiographic views that are unique to the chiropractic profession and utilized for locating and measuring spinal subluxations.

We have determined a set of 19 radiographic views and motion x-ray that are utilized in different chiropractic technique and clinical methods for the assessment of spinal subluxation. After listing these radiographic views, there is a description of each view with a discussion of reliability, validity, and clinical utility of each view. For convenience of categorization, we have placed these radiographic views into classifications by the region visualized on the film, i.e., cervical, thoracic, lumbar, pelvic, full spine, lower extremity, motion x-ray for trauma.

The sheer number of clinical studies using these 19 radiographic views is overwhelming and to discuss and reference many of these efficacy studies makes this section the largest section in this document. Contrary to the Level V evidence espoused by a subgroup of DACBRs and Chiropractic Academics, there are a plethora of publications on the efficacy of radiographic utilization in chiropractic clinical practice.

**Section XI. Pediatric Radiographic Evaluation in Chiropractic**

There are many different ways (birth traumas and impact traumas) that a child may be injured. Several of these traumas are referenced. Additionally, there are certain developmental stages of the spine that the clinician should be aware of when taking x-rays of a child. There are also some specific child health problems listed. The numerous possible traumas to children, who often are too young and cannot communicate their symptoms, creates the necessity of a radiographic examination. There are numerous chiropractic Case studies that report the necessity and outcomes of a radiographic examination for subluxation analysis and correction in the pediatric case.

**Section XII. The Presence of Abnormal Posture and Any Axial or Radicular Pain Requires a Radiographic Evaluation**

In recent decades there has been a plethora of published studies concerning mechanoreceptors (Types I-IV) in the spinal ligaments (ALL, PLL, ligamentum flavum, intertransverse, facet capsular, interspinous, and supra spinous) and intervertebral discs. Not only do these structures (ligaments & discs) have a nerve supply, but these mechanoreceptors inform the brain of spinal position, and they create reflexes that connect in the spinal cord with the sympathetic chain. The perception of pain comes from deformed mechanoreceptors. This deformation comes from the 6 types of spinal subluxations previously defined in this document. Deformation (strain) is caused by abnormal loads and stresses. Besides pain, Woff’s Law (bone
remodels to stress) and Davis’ Law (soft tissue remodels to stress) indicate that abnormal spinal positions (the 6 subluxation types) are the cause of many pathologies in the spinal structures.

Thus, the presence of pain is an “Indication” for the necessity of a radiographic evaluation in order to identify a possible spinal subluxation as a cause of such pain.

Section XIII. Legal Obligations of a DC for radiographic Use (Case Law, Judge’s Decisions)

An overwhelming majority of states extend broad diagnostic X-ray privileges to licensed chiropractors by statute, either expressly or implicitly. Many states require their licensure examinations to test the applicants’ knowledge of X-ray diagnosis and technique. Furthermore, in several states the eligibility requirements for a license demand a minimum number of hours spent studying X-ray diagnosis and technique. Our brief search revealed that at least forty (40) states are characterized by one or more of the previous statements.

The PCCRP panel conducted a thorough search of federal and state cases involving chiropractors and their standard of care applicable to both the use and lack of use of diagnostic X-rays. Upon completing this search the PCCRP panel concludes that the relevant case law yields no uniform standards which suggest chiropractors should limit their use of diagnostic X-rays to “Red Flag” cases.

The “respectable minority doctrine.” The most common legal definition of standard of care is how a group of similarly qualified practitioners would have managed the patient's care under the same or similar circumstances. This is not simply what the majority of practitioners would have done. The courts recognize the respectable minority rule. A number of states recognize it as a malpractice defense that the defendant acted in accordance with the custom of at least a "respectable minority," or recognized subgroup, of the relevant profession, even though his or her actions were at odds with mainstream professional practice.

1. Chiropractors are authorized to employ spinal x-ray examinations in all 50 states of the U.S.
2. Statutes, rules and regulations concerning the practice of chiropractic do not explicitly limit the use of x-ray examinations to cases where “red flags” are present.
3. Some courts have explicitly upheld the use of chiropractic x-rays to detect or determine the presence of spinal subluxations.
4. Courts generally recognize that standard of care may be established under the respectable minority rule.