

Chapter Outline

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I. OVERVIEW

The purpose of all imaging technologies utilized by the chiropractic profession is primarily to gain analytical information concerning the vertebral subluxation and other malpositioned articulations and structures. Historically, basic radiography has been the sole imaging modality used. Although basic radiography continues to be the primary imaging technology for chiropractic analysis, recent developments in imaging technology have provided additional methods for gaining visual information about the vertebral subluxation and other malpositioned articulations and structures.

This document presents the current knowledge concerning the proper utilization of imaging technology with particular emphasis on the clinical rationale, necessity, and significance of these technologies. It is not intended for this document to be a definitive work, but rather a basic framework which will be expanded as new information is gained through ongoing research in this subject area.

Analysis of the vertebral subluxation complex often depends upon examination procedures requiring interpretation by the chiropractor.

Traditionally Chiropractic has defined the vertebral subluxation in terms of four criteria:

1. Loss of juxtaposition of a vertebra with the one above, the one below, or both.
2. Occlusion of an opening.
3. Nerve impingement.
4. Interference with the transmission of mental impulses.

A contemporary definition of the vertebral subluxation complex proposes a minimum five components:

1. Spinal kinesio pathology consisting of abnormal vertebral position, motion, or lack of motion.
2. Neuropathology due to compression, stretching, or irritation of neural tissue.
3. Myopathology characterized by hyperactivity, spasm, weakness, atrophy, or fibrosis.
4. Histopathology including swelling, inflammation, degeneration, and other abnormalities occurring at the cellular and tissue level.
5. Bio-chemical changes/pathology consisting of local damage to the spine and contiguous soft tissues, and pathology in peripheral structures such as viscera, muscles, and glands. (Lantz)

Both models incorporate biomechanical, bio-chemical and pathophysiological components. In clinical practice, documenting and quantifying these changes poses a formidable challenge. A number of procedures have been employed in chiropractic practice to detect and characterize vertebral subluxations including but not limited to:

1. Detection of biomechanical and structural abnormalities
 - A. Postural analysis
 - B. Static palpation
 - C. Motion palpation
 - D. Static radiography
 - E. Functional radiology, including videofluoroscopy
 - F. Computed tomography
 - G. Magnetic resonance imaging

2. Detection of neurophysiological changes
 - A. Orthopedic examination
 - B. Neurological examination
 1. Reflexes
 2. Muscle tests
 3. Dermatome examination
 4. Functional leg checks
 5. Nerve tracing
 - C. Thermography
 - D. Electrodiagnostic studies

II. RATIONALE FOR UTILIZATION OF IMAGING TECHNOLOGIES

A. Prime Directive

Imaging methods shall be utilized for the purpose of obtaining information concerning the vertebral subluxation and other malpositioned articulations and structures, primarily the misalignment component, although advanced imaging can also provide important information regarding foraminal alteration, nerve impingement, and aberrant motion.

The use of such procedures shall be based on gathering clinical evidence that vertebral subluxation and other malpositioned articulations and structures is present in the patient. The danger of ionizing radiation, present in most imaging, contraindicates the use of these procedures without clinical justification. The use of non-ionizing procedures should be governed by accepted clinical protocol with the primary concern being for the patient's safety.

B. Secondary Directives

1. Selection of Adjusting Technique

Imaging procedures may be utilized to provide information concerning the physical structure of the patient's spinal column, skull, and pelvis and/or other articulations of the skeleton, for the purpose of selecting or modifying an adjusting technique appropriate to the unique anatomic structure of that patient.

2. Contraindication Disclosure

Imaging procedures may be utilized to disclose possible contraindications to the application of adjustic forces to the spine.

C. Tertiary Directive

To protect the patient's overall welfare, the doctor shall inform the patient of all findings

disclosed by an imaging procedure.

The doctor shall inform the patient of those findings which are normally found in such an examination, and distinguish those normal findings from any which are unusual.

III. RISK/BENEFIT ANALYSIS

The risk/benefit analysis is a theoretical model that governs the practice of health care. It provides a paradigm within which the merits of a health care procedure can be discussed. Simply put, only those procedures which are predicted to have a greater likelihood of providing a benefit to the patient than they have of causing the patient harm are justified. It is theoretical since the risk/benefit odds associated with a procedure and any one individual patient cannot be specifically quantified.

A. Adult patients

The risk associated with obtaining a radiographic image utilizing maximum safety procedures, of the adult patient, is minimal. With demonstration of clinical necessity, the benefit of such a procedure to the analysis of the vertebral subluxation and other malpositioned articulations and structures, and thereby to the patient, is high. The risk/benefit analysis favors the use of radiographic producers in the adult patient.

14 x 36 FULL SPINE RADIOGRAPHY

Full spine radiography has always been an integral part of the science of chiropractic. Studies preclude common misconception about full spine radiography. Advances in technology continue to reduce radiation exposure in these procedures. Plaughter/Lopes states, "With the advances in taking full spine radiographs, the patient is exposed to less radiation than standard sectional views when the entire spine must be visualized."

In certain circumstances, the doctor of chiropractic has employed so-called "split screen" techniques. Split screens compensate for differences in body part thickness by using intensifying speeds of different speeds in the same cassette. For example, lower speed screens may be used in the cervical region, and faster screens in the lumbar-pelvic region. Today, such techniques are obsolete. Instead, supplemental filtration is used to compensate for differences in body part thickness, and single-speed screens are used. Dosimetry studies using supplemental filtration and single-speed screens revealed that the 14 x 36 AP spinograph actually resulted in lower radiation levels than sectional AP films of like sized subjects.

As Hildebrandt observed, "It has been shown that it is possible to produce reasonably good diagnostic quality full-spine roentgenographs with less radiation exposure to the patient than when the same full spine areas are exposed by smaller sectional views." Phillips states, "Anteroposterior views of the spine on a 14 x 36 inch exposure can be produced with acceptable quality." Hildebrandt cites a comparative study conducted by the Bureau of Radiological Health stating, "In this study, it was shown that it was in fact possible to obtain diagnostic full-spine films with a skin dose exposure as low as 128.8 mR, while separate lumbar and thoracic films taken according to standard exposure practices delivered 166.1 and 184.5 mR respectively. Buehler and Hrejsa evaluated lead-acrylic compensating filters in chiropractic full spine radiography. They concluded that this system "is capable of producing full spine radiographs with good to above average imaging quality." It was further noted that this filtration system was generally equivalent in radiation dose reduction to other systems.

The criticism that the distortion inherent in 14 x 36 radiographs precludes accurate biomechanical assessment also seems unfounded. Plaughter and Hendricks evaluated the inter-examiner reliability of the Gonstead pelvic marking system. Concordance on exact numerical

values was poor. However, from a clinical standpoint, agreement for categorizing listings was impressive. Inter-examiner concordance for listings of the ilia, sacrum, symphysis pubis, and femur head height was evaluated by calculating the kappa values for each. The resulting kappa values ranged from .4849 (moderate) to .8161 (excellent).

In addition to Gonstead pelvic analysis, proponents of 14 x 36 full spine radiography also use the procedure to evaluate vertebral body rotation and lateral flexion malposition. Zengel and Davis investigated how projectional distortion affects such determinations. They concluded, "as long as a given osseous segment is compared to its adjacent segment (as in analysis for subluxation), the apparent vertebral rotation may be regarded as a sufficiently accurate representation of the actual rotation of the vertebra." In reference to vertebral endplate lines used to assess lateral flexion malpositions, these authors stated, "In every instance, off centering produced no measurable effect on the position of the constructed Gonstead lines. We therefore conclude that these lines may be confidently used. No correction for projectional distortion seems necessary." Logan and Barge analytical methods have been used in chiropractic to determine vertebral rotation. The Bunnell method is a recognized medical procedure employed by that profession to determine rotational deviations.

CERVICAL SPINE RADIOGRAPHY

Sigler and Howe conducted an inter- and intra- examiner reliability study of a method for measuring atlas laterality. Twenty x-rays were marked by three different doctors. This study concluded that because of the ranges of error, differences produced using this system will be just as likely due to marking error as from actual atlas position change. Although frequently cited by those opposing upper cervical spinographic analysis, this study has several significant shortcomings. These include small sample size and a conclusion which cannot properly be drawn from the data presented.

Other studies have yielded results supporting the reliability of cervical spinographic techniques. Grostic and DeBoer did a retrospective study of 523 patients evaluating roentgenographic measurements of atlas laterality and rotation pre and post adjustment. Statistically significant changes in the postulated direction of atlas positioning were reported. Jackson et al studied the inter- and intra-examiner reliability of upper cervical x-ray marking. Six practitioners evaluated thirty radiographs. The study revealed very good intra- and inter- examiner reliability for the procedure employed. Leach investigated the effect of chiropractic care on hypolordosis of the cervical spine. A significant improvement in the cervical curve was noted in patients receiving chiropractic care. Barge's observations in Cobb angle reductions in scoliosis also reported reduced cervical angulation through chiropractic adjustive care. Before and after x-rays in torticollis often indicate improved cervical alignment following a course of chiropractic adjustive care.

The radiation burden for upper cervical spinography is minimal, particularly when compared to radiation intensive imaging techniques such as CT scanning. Although it is sometimes argued that post adjustment studies double the radiation dose to the patient, this is generally untrue. Post adjustment studies typically involve fewer exposures than the initial series. Although cervical spine radiography does expose radiosensitive tissues (such as the thyroid gland) to the useful beam, the information gained generally justifies the study. This is particularly true when rare earth screens and fast films are employed, and when the presentation of future chronic spinal distortions are anticipated.

B. Pediatric patients

The risk associated with obtaining a radiographic image of the pediatric patient, those under 16, is higher than that of the adult patient due to the fact that ionizing radiation is more

damaging to rapidly dividing cells. The benefits of such procedures are the same as they are for the adult patient. The risk/benefit analysis favors discretion in the use of radiographic procedures in the pediatric patient.

The doctor of chiropractic is responsible for determining the safety and appropriateness of chiropractic care. This responsibility includes the detection and characterization of vertebral subluxations and other malpositioned articulations and structures as well as examining for conditions where chiropractic care is contraindicated or referral to another health care provider is indicated. In children, the accurate evaluation and early intervention in certain spinal cases provides a defensible rationale for employing x-ray analysis as some structural distortions, such as scoliosis, can most effectively be addressed in the childhood years

RADIATION SAFETY

Plain film radiography has been the mainstay of imaging in most chiropractic practices. Growing concern for the hazards of ionizing radiation and the availability of alternative imaging techniques may cause this to change. According to a recent National Research Council report, low doses of x-radiation pose a human cancer risk three to four times higher than previously reported. The report also noted that some fetuses exposed to radiation face a higher than expected risk of mental retardation.

This does not mean that the chiropractor should abandon plain film radiography. It does mean developing increased awareness of the judicious use of ionizing radiation, and implementing radiographic procedures which minimize risk and maximize the amount of information obtained from the study. Radiation protection is particularly important when x-raying infants, children, adolescents, and adults in their reproductive years. It has been stated that "For examination of the skeleton, there is no modality to match the time and cost effectiveness of the plain film radiograph."

The 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 benefits vs. risks determinations in selecting radiographic procedures. A Bureau publication states, in part:

In almost every medical situation, when the physician feels there is reasonable expectation of obtaining useful information from roentgenological examination that would affect the care of the individual, potential radiation hazard is not a primary consideration. . .The physician should retain complete freedom of judgment in the selection of roentgenologic procedures, and (the physician) should conform with good technical practices.

In selecting any examination, it has been suggested that a given procedure be considered "necessary" under the following circumstances:

1. The outcome of the test will be used in determining the nature of the care administered.
2. The test itself is reliable.
3. More cost effective procedures that are equally reliable or more reliable are not available.

The following are indications for pediatric radiologic examination:

1. History of trauma with clinical signs suggestive of fracture or dislocation.

2. Clinical suspicion of infection or neoplasm.
3. Clinical evidence of a congenital or developmental anomaly which could alter the nature of the chiropractic care rendered, or which may itself require care.
4. When clinical findings are equivocal, and the suspected condition can be detected or ruled out by plain film radiography.
5. When other examination procedures fail to disclose the nature of the condition, and the patient is not responding favorably to care.
6. To characterize the biomechanical component of the vertebral subluxation and other malpositioned articulations and structures complex when such characterization is necessary to render chiropractic care, and less hazardous alternative examinations are not available.
7. To evaluate patient response to chiropractic care when such evaluation may alter the nature of the care being rendered, and less hazardous alternative examinations are not available.

PEDIATRIC RADIOLOGY OF THE SKELETON

Trauma is the most frequent indication for skeletal radiographic evaluation. In addition, congenital, neoplastic, and infectious conditions may warrant x-ray studies. Accurate interpretation of pediatric radiographs is dependent upon an understanding of the appearance of ossification centers at various stages of development, and an appreciation of normal radiographic anatomy. A history of spinal curvatures, such as scoliosis, also indicates the possible need for x-ray evaluation of the pediatric spine.

Evaluation of pediatric spine films also requires that the doctor interpreting the films understand the pitfalls involved in imaging pediatric spines. Patient motion is an ever-present problem. Even when short exposure times are used to limit the effects of motion on the finished radiograph, a true postural study may be difficult to obtain. Immobilization of an uncooperative patient may yield a film that is useful diagnostically, but may not accurately depict subluxation related pathomechanics.

VARIATIONS IN DEVELOPMENT

A lack of segmentation of the primitive sclerotome results in a "block vertebra." In this condition, two vertebrae appear structurally as one, and function as one. The failure of the non-segmented vertebra to contribute to the composite motion of the region affected may lead to hypermobility and degenerative changes at other segmental levels. When non-segmentation occurs at the occipito-atlanto articulation, the term "occipitalization" is applied. While non-segmentation by itself rarely produces neurological compromise, brainstem or cord compression have been reported in cases of upper cervical fusion.

Other variations may also occur in the upper cervical spine. In children, the atlanto-dental interspace should not exceed 5 mm. An increase may be due to congenital absence of the transverse ligament as seen in Down's syndrome. Although previously considered of little clinical significance, increased participation by such children in athletic activity requires careful assessment of the upper cervical spine. Flexion-extension studies are advocated for such children to assess possible atlantoaxial subluxation. Juvenile rheumatoid arthritis or traumatic rupture of transverse ligament may also result in an increased atlanto-dental interspace.

Variations also occur in the development of the odontoid process. The tip of the dens

develops from an ossification center which appears at age 2 and unites at 10 to 12 years. If such union does not occur, a terminal ossicle remains. If the dens remains ununited at its base, the condition is termed os odontoideum. Instability and cord compression may result. Hypoplasia or congenital absence of the dens may also occur, resulting in an unstable articulation.

A number of additional variations have been reported which may be encountered by the chiropractor:

1. Klippel-Feil Syndrome. This condition is characterized by multiple block vertebrae of the cervical spine. The patient may present with a short neck, low hairline, and genitourinary anomalies. The condition predisposes the spine to injury and possible cord damage.
2. Sprengel's deformity. Congenital non-descent of the scapula can often be detected clinically. Radiographs will demonstrate an omovertebral bone in 30-40% of cases.
3. Cervical ribs. Ribs may arise from a lower cervical segment. These ribs may cause neurovascular compression (scalenus anticus syndrome) later in life. In children they are usually asymptomatic.
4. Butterfly vertebra. A sagittal cleft in a vertebral body may occur, usually in the thoracic or lumbar spine. Most are asymptomatic and clinically insignificant.
5. Hemivertebra. Failure of the lateral half of a vertebral body to develop produces a lateral hemivertebra. The inevitable consequence is a scoliosis. Rarely, a dorsal or ventral hemivertebra occurs, which may cause an alteration of lordotic and kyphotic curves.
6. Spina bifida. Spina bifida occulta is a failure of fusion of the posterior elements of a spinal segment without meningeal protrusion. It is often seen at the L-5 level, and is usually of minimal to no clinical significance. It does not generally perceived to increase susceptibility to athletic injury. As with any other abnormal structural variation the presence of spina bifida occulta may warrant examination in greater detail than would a normal spine. Spina bifida manifesta or vera, however, leaves the cord unprotected and is a serious condition.
7. Facet tropism. Asymmetry of the facets at the L5/SI level may produce asymmetrical biomechanics and joint dysfunction.
8. Knife clasp deformity. Spina bifida occulta in association with an elongated LS spinous process may result in painful and limited extension.
9. Transitional vertebrae. Lumbarization of SI or sacralization of L5 may occur. Tini, Wieser, and Zinn examined 4000 radiographs and concluded that persons with transitional vertebra did not exhibit any more backaches than controls. Abnormal mechanics produced by the condition, however, may lead to premature disc degeneration at other levels.
10. Defects in the pars interarticulars that may lead to spondylolisthesis may also indicate need for restrictive exercise activities and competitive sports due to susceptibility to injuries.

In addition to structural variation, functional variation in the pediatric spine warrants careful

consideration by the chiropractor. Sullivan et al examined lateral cervical radiographs on 100 normal children, and discovered that in 20% of cases C2 appeared subluxated anteriorly on C3. This phenomenon is usually observed in children under 9 years of age, and is due to the more horizontal facet orientation in the younger child. It is particularly pronounced in flexion.

Cattell reported that 15% of normal pediatric spines demonstrate absence of the cervical lordotic curve or a single level kyphosis. Whether these "normal" findings represent early changes predisposing to subluxation degeneration has not been explored. Following subjects with these purportedly "normal" "pseudosubluxations" throughout life, and comparing the incidence of degenerative changes in the spine with controls is suggested as an area for additional research.

PEDIATRIC SPINE FRACTURES

Children under 16 account for 7% or less of injuries to the spine. Although pediatric spine injuries are relatively uncommon, their prompt recognition and proper management are essential in chiropractic practice.

Motor vehicle (including motorcycle) accidents account for over 50% of the injuries, with team sports, diving injuries, and gunshot wounds accounting for most of the rest. The most common areas of injury are the cervical spine and the thoracolumbar junction. It is suggested that in cases of spinal trauma, plain AP and lateral radiographs be taken of the entire cervical, thoracic, and lumbar spine. This is due to the high occurrence of contiguous and non-contiguous injuries. If an abnormality is detected on plain film, computed tomography (CT) may be useful in characterizing bony abnormalities. In cases of neurological involvement, magnetic resonance (MR) imaging is the technique of choice.

Denis et al reported that 50% of deaths due to pediatric spine injuries were associated with injuries to the occipito-atlanto complex. According to Henrys et al upper cervical injuries are more common in children and adolescents. The Powers ratio can be used to assess such injuries on plain radiographs. Jefferson fractures are rare in children. Two cases, aged 7 and 12 years, have been reported in the literature. The most frequently encountered fracture of the axis is the dens fracture although five cases of bilateral pedicle (hangman) fractures in children were reported by Pizzutillo et al. Lower cervical spine fractures are seen more frequently in adolescents than young children. Most are associated with flexion-compression injuries in collision sports.

A variety of fractures may present in the pediatric thoracic and lumbar spine. The most common vertebral fracture seen in children under 10 years of age is the compression fracture. The cause is a compressive flexion force. Seatbelt injuries result in a compressive distractive force. Fracture through the bone as well as soft tissue damage may result. Unlike the compression fracture, which usually does not result in significant morbidity, the seat belt fracture may require bracing, casting, or surgery. Spondylolysis has been related to extension-flexion injuries, and its early detection can help prevent a lifetime of chronic problems. Gunshot injuries and child abuse are other causes of spine fractures. Avulsion fractures of the spinous processes in the cervical spine and compression fractures in the thoracic and lumbar region may occur as a consequence of violent shaking.

PEDIATRIC SPINE NEOPLASMS

Spine tumors in children are uncommon. While it is estimated that 80% of adults will seek professional care at some time for back pain, only 2% of children and adolescents presenting at an orthopedic clinic complained of back pain. Spine tumors in children may be primary benign tumors, primary malignant tumors, or metastatic tumors.

Primary Benign Tumors

- a. Osteochondroma. This tumor is simply an exostosis. It is the most common benign tumor of bone, although only 2% occur in the spine. They rarely cause symptoms.

Osteoid osteoma. About 1% of spine tumors are osteoid osteomas, seen more frequently in males than females, and usually appearing between the ages of 10 and 25 years. The posterior elements are involved more frequently than the vertebral body.

The lumbar spine is affected more frequently than the cervical or thoracic region. Localized pain, worse at night, and relieved by aspirin is characteristic. Osteoid osteoma is the most frequent cause of a painful scoliosis.

Osteoblastoma. Approximately 40% of these lesions occur in the spine. Most patients are under 30 years of age, and the posterior elements are involved more frequently than the vertebral bodies. Like osteoid osteoma, pain is frequently the presenting symptom. Unlike osteoid osteoma, however, the pain is not worse at night. Neurological deficit is present in over 50% of cases.

- b. Aneurysmal bone cyst. Although these tumors account for only 1% of primary bone tumors, 11 to 22% occur in the spine. These lesions are usually painful. Neurological deficit may result from the expansile nature of the lesion.

- c. Eosinophilic granuloma. This lesion occurs in the second or third decade of life, and may not be a true neoplasm. The clinical presentation is often that of an adolescent with back pain. Vertebra plana often occurs, but neurological deficit is rare. In the absence of neurological deficit, the condition is self limited, and reconstitution of height is the rule. This condition was previously reported as Calve's disease, incorrectly believed to be a form of juvenile ischemic necrosis.

Primary and Metastatic Malignant Tumors

Multiple myeloma. This tumor usually occurs in patients over 50 years of age, but rarely is seen in young patients. Multiple lytic lesions and altered serum proteins are characteristic.

Ewings sarcoma. This tumor rarely involves the spine, but when it does, localized pain is usually present. The 5-20 year old age group is most affected. Metastasis may occur. This is an aggressive and potentially fatal tumor.

Lymphoma. This rare condition may be seen in young adults. An "ivory vertebral" appearance is characteristic. Metastasis may occur. This is another potentially fatal tumor.

Osteosarcoma. Primary involvement of the spine is rare, and spinal osteosarcoma is usually due to metastasis. Less than 2% originate in the spine. The condition is most commonly seen in the second decade of life. Spinal involvement may be difficult to treat. The condition is potentially fatal.

Chondrosarcoma, fibrosarcoma, and chordoma rarely occur in children or adolescents. Metastasis to the spine in children is most frequently from neuroblastoma and leukemia.

PEDIATRIC SPINE INFECTIONS

Infections in the pediatric and adolescent spine are uncommon in the United States. When infections do occur, the route is usually hematogenous. There are four main categories of pediatric spinal infections.

Discitis. This condition usually follows a benign course. Low grade fever, irritability, back

rigidity, muscle spasm, and tenderness may present clinically. Care consists primarily of immobilization and rest. Antibiotics are sometimes employed.

. Non-tuberculous vertebral osteomyelitis. This rare condition is far more serious than disc space infection. Toxemia may be evident. High fever may occur, and the child appears very ill. Back pain may or may not be present. *Staphylococcus aureus* is the most common bacteria isolated.

Tuberculosis of the pediatric spine. The age of onset of this condition is usually between 2 and 5 years of age. The usual site is the thoracic and lumbar vertebral bodies. A reversal of the height:width ratio of the vertebral bodies may occur. The condition may lead to neurological involvement and skeletal deformity.

Spinal epidural abscess. These are among the most serious infections of the spine, and may lead to paraplegia and death. The patients often present with pain, high fevers, and appear very ill. Unlike osteomyelitis, however, plain film radiographs often appear normal. Magnetic resonance imaging is the technique of choice in such cases.

ADOLESCENT IDIOPATHIC SCOLIOSIS

Scoliosis may be due to muscular imbalance, structural asymmetry such as congenital malformations, decompensation of adaptational curves, or may be idiopathic. At one time adolescent idiopathic scoliosis was now considered a purely hereditary condition. Recent investigators have reported abnormal proprioceptive function believed due to a posterior column abnormality. Abnormal writing reflex functions may be related to balance mechanisms located in the brain stem or in the spine. Abnormal vibratory sensation in both upper and lower extremities suggests that the lesion is located in the cervical spinal cord. The role of the vertebral subluxation and other malpositioned articulations and structures complex in this process deserves further study as evidence is accumulating to indicate positive outcomes achieved through chiropractic care.

SCHEURMANN'S SYNDROME

This condition is sometimes known as juvenile kyphosis. The etiology is controversial, but is generally believed due to an abnormality of the cartilaginous end plate. This results in anterior Schmorl's node formation. The 13-17 age group is most frequently affected.

LEGG-CALVE-PERTHES DISEASE

Legg-Calve-Perthes disease is an avascular necrosis affecting the capital femoral epiphysis. Males are affected more than females. The condition is usually unilateral. Weight bearing may lead to deformity. The disease is self-limited.

OTHER EPIPHYSEAL DISORDERS

Numerous eponymic disorders of developing epiphyseal centers have been described. Some are believed due to trauma or overuse (e.g. Sever's disease of the Os calcis and Osgood-Schlatter's disease of the tibial tubercle). Others are believed due to osteonecrosis.

SPONDYLOLYSIS AND SPONDYLOLISTHESIS

The incidence of spondylolysis is 4 to 6%. It is several seen before the age of 5, and most cases occur during the adolescent growth spurt. Most authors now view spondylolysis as a stress fracture. Anterior displacement of the involved vertebral body may lead to spondylolisthesis and pathomechanical changes. The association of the condition with back pain is highly variable.

Plain film radiography is the mainstay of imaging in most chiropractic practices. The use of ionizing radiation in examining any patient, including children and adolescents, should be based on clinical need. The primary responsibilities of the doctor of chiropractic include determining the safety and appropriateness of chiropractic care, locating and correcting vertebral subluxations and other malpositioned articulations and structures, and the correction of aberrations from normal that may lead to future spinal curvatures. The judicious use of various imaging techniques may be invaluable in achieving these objectives.

A. Pregnant women

The risk/benefit analysis favors avoidance of radiographic procedures in the pregnant woman, especially in the 1st trimester.

A Bureau of Radiological Health publication states: In almost every medical situation, when the physician feels there is reasonable expectation of obtaining useful information from roentgenological examination that would affect the care of the individual, potential radiation hazard is not a primary consideration...the physician should retain complete freedom of judgment in the selection of roentgenologic procedures, and (the physician) should conform with good technical practices.

B. Radiation therapy patients

The risk/benefit analysis favors discretion in use of radiographic procedures in the radiation therapy patient.

C. Rebalancing of the risk/benefit analysis equation

The risk/benefit analysis is a dynamic thought process, and as such, is subject to a rebalancing that may countermand the general guidelines as in the following situations:

1. Trauma: The presence of trauma may increase the benefit portion to an extent which supercedes the risk portion and provide, for the use of radiographic procedures in a patient for whom such procedures were previously contraindicated.
2. Negative changes in the patient's general health: The presence of negative changes in the patient's general health may increase the benefit portion to an extent which supersedes the risk portion and provide for the use of radiographic procedure in a patient for whom such procedures were previously contraindicated.
3. Surgery: Surgical procedures may increase the benefit portion to an extent which supersedes the risk portion and provide for the use of radiographic procedures in a patient for whom such procedures were previously contraindicated.
4. Unusual or unexpected reaction to an adjustive procedure: A severe reaction to an adjustive procedure may increase the benefit portion to an extent which supersedes the risk portion and provide for the use of radiographic procedures in a patient for whom such procedures were previously contraindicated.
5. Patient history: A family history of back pain, spondylolysis, congenital abnormalities, scoliosis and other curvatures may also increase the benefit portion.

IV. LIST OF SUBTOPICS

- A. Plain film radiography
- B. Video fluoroscopy
- C. Magnetic resonance imaging
- D. Computed tomography
- E. Ultrasonography
- F. Contrast studies
- G. Radioisotopic scanning
- H. Services/billing

V. RECOMMENDATIONS

- A. Plain film radiography

Purpose:

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.
6. To provide information concerning abnormal spinal contours.
7. To detect anomalous structures that may contribute to spinal distortions, sacral plateau abnormalities, etc.

Clinical Necessity

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 as well as determining the presence of spinal and/or extraspinal pathology, injury, or developmental variation.

Technical consideration

1. Machine selection: General guidelines (ALARA & AHARA) provide for the use of machine that will produce the best image possible with the lowest patient dosage.
 - a. Single phase units: These units are acceptable but provide for greater patient exposure than other types of equipment.
 - b. Three phase units: These units provide superior image quality with patient dosages which are lower than single phase.
 - c. Medium or high frequency units: These units provide image quality that is superior to single phase, with patient dosages comparable to three phase, and the advantage of easier installation.
2. Film/screen combinations: General guidelines provide for the use for a film/screen combination that will provide for acceptable image quality with the maximum reduction

in patient dose.

3. KVP/MAS Selection: General guidelines provide for the use of a fixed KVP/variable MAS technique to provide maximum image quality with optimum patient safety.
 - a. KVP: An optimum kilovoltage should be utilized for the region of interest. This selection should be based on the machine and film/screen manufacturer's specifications.
 1. MAS: Milliampere seconds should be governed by the measured thickness of the region of interest or by an automatic exposure control (ARC) system. This selection should be based on the machine and film/screen manufacturer's specifications.
4. FFD/SID Selection: General guidelines provide for the use of a distance appropriate to the OFD/PFD.
 - a. A shorter distance (40") is appropriate when the OFD/PFD is zero.
 - b. A longer distance is appropriate when the OFD/PFD is anything other than zero.
5. Filtration: General guidelines provide for the use of filtration to reduce patient dose.
 - a. Inherent filtration: This is primarily a manufacturer's specification in accordance with the WCRP recommendation #33.
 - b. Added filtration: This should be utilized to reduce the patient dose over region of interest where the use of a shield would limit analytical value, and for visually equalizing areas of the patient's body which are of unequal radiographic density.
6. Grids: General guidelines provide for the use of grids to prevent secondary radiation from reaching the film. The use of grids improves radiographic quality and should be employed as per manufacturer's specification.
7. Shielding: General guidelines provide for the use of shielding to eliminate patient dose over radiosensitive areas.
 - a. Collimation: Maximum collimation to limit the primary beam to the area of interest is the primary method of eliminating unnecessary radiation exposure.
 - b. Gonadal shielding: This is most appropriate for the male patient, since the gonads are not in the region of interest of a spinograph. It may also be used on the female patient if the doctor is not seeking to obtain analytical information from an area which would be obscured by the shield.
 - c. Lead apron shielding: A lead apron may be employed to eliminate possible primary beam exposure of the patient in areas other than the region of interest. This type of shielding is of little practical value however, if close collimation is

employed.

8. Processing: General guidelines provide for the use of optimum darkroom technique to obtain the maximum image quality. Manual or automatic processing techniques are acceptable.

Analysis

1. Minimum initial study: Regional studies generally include a minimum of two views taken at opposition of 90 degrees. Exceptions, however, are not uncommon, such as examination of the pelvis and some post-adjustment films which need only be a single view. The clinical judgement of the attending doctor shall determine the needs of each patient, with due regard to minimizing radiation exposure.
2. Extra views: Additional views shall be added as clinically indicated to provide full analysis.
3. Regional studies: Views may be obtained either by region of interest or in full spine as required by the technique selected. Due to the dangers inherent in the radiographic process, only those areas of clinical interest shall be x-rayed.
4. 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.
7. Repeat studies: Due to the dangers inherent in radiation exposure, repeat studies should only be used as clinically required.

15.1.1. **Rating:** Strong Positive Recommendation
Strength: I, L

B. Videofluoroscopy

The first known fluoroscopic image was produced by Roentgen in 1895. Roentgen placed his hand between an x-ray source and a fluorescent screen, and was astonished to see an image of the bones of his hand on the screen. One year later fluoroscopic screens became available, and the technique was employed for 'real time', observation of human structures. In the 1950's, electronic image intensification systems became readily available. Using electronic image intensification, the fluoroscopic image is amplified, resulting in an improvement in image quality and a reduction in radiation levels. When the image is recorded on motion picture film, the procedure is termed cineradiography. If a video recording is made, the term videofluoroscopy is employed.

In chiropractic, a leading pioneer in spinal fluoroscopy was Earl Rich. Fred Illi employed the technique in studying spinal biomechanics. Joseph Howe conducted fluoroscopic studies of the spine, and reported instances where the technique revealed abnormalities not demonstrated on plain films. Current chiropractic interest in fluoroscopy is evidenced by the formation of the Joint Motion Study Research Society, and the offering of certificate courses in videofluoroscopy by CCE accredited chiropractic colleges.

TECHNIQUE

A videofluoroscopic system consists of an x-ray generator capable of operating at low (1/4 to 5) milliamperage settings, an x-ray tube assembly, an image intensifier tube, a television camera, a

VCR, and a monitor. The heart of the system is the image intensifier tube. This tube permits imaging at very low radiation levels. It is used instead of intensifying screens and film as an image receptor.

An image intensifier tube consists of four key components in an evacuated glass envelope:

1. Input phosphor and photocathode. The input phosphor is similar to the intensifying screen used in conventional radiography. It emits light when energized by x-rays. When light from this screen strikes the photocathode, electrons are emitted.
2. Electrostatic focusing lens. A series of electrically charged plates focus the electron beam as it flows toward the output phosphor.
3. Accelerating anode. This positively charged electrode is located in the neck of the tube. It accelerates the electrons toward the output screen.
4. Output phosphor. The output phosphor produces light when energized by electrons. It is coupled to a television camera.

The signal from the video camera is fed to a monitor and VCR, where it can be observed and recorded.

CLINICAL APPLICATIONS

In considering the use of any examination employing ionizing radiation, the clinician should ask:

1. Does the potential yield of information justify the exposure?
2. Will the outcome of the study affect the care or management of the case?
3. Are less hazardous, equally reliable techniques available?

Several authors have addressed these issues. Observational and case studies have appeared in the literature comparing the diagnostic yield of fluoroscopic studies vs. plain films. In addition, studies have been published reporting abnormalities detected by fluoroscopy which could not be appreciated on plain films.

Bland states, "Clearly, cineradiography is the best method for the study of biomechanics and dynamics of motion in the cervical spine. . .The determination of normal motion, sites of greatest and least motion, contribution by joints, discs, ligaments, tendons, and muscles to motion (and their limitations), and the biomechanics of normal motion of the occiput-atlas-axis complex all have been studied very successfully through cineradiography." According to Ochs, "Cineradiography, using film or videotape, is shown in a study of 34 painful or injured necks to be a valuable clinical tool. It is useful in fracture management, analysis 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."

Buonocare, Hartman, and Nelson examined the cervical spines of 107 patients using cineradiography, including 57 who sustained flexion-extension injuries. They concluded, "The ability to demonstrate localized abnormal motion in the cervical spine allows one to predict soft-tissue injuries and the quality of spinal fusions, spinal stability, and early subluxation of the cervical spine-conditions that may not be identified on static roentgenograms nor at physical examination."

Jones studied abnormalities of the upper cervical spine using cineradiography, and concluded, "Cineradiography has been used to detect instability not ascertainable by routine roentgenograms obtained in flexion and extension...." In a case study of abnormal atlanto-axial motion, Tasharski

noted, "Interpretation by means of standard static radiographs failed to disclose the nature of the functional post-traumatic disorder. Cinefluorographic visualization of the articulation in motion demonstrated abnormal mobility." Woesner and Mitts also concluded that fluoroscopic studies often revealed abnormalities undetected on plain films.

They stated, "There were, however, a significant number of instances in which cineroentgenography demonstrated abnormal motion not detected on conventional roentgenograms. Cineroentgenography is, therefore, a valuable adjunctive technique and its continued utilization in the analysis of cervical spine motion is justified."

Numerous applications for spinal fluoroscopy have been reported in the medical literature. These include recording the effects of cervical spine traction, evaluating cervical spine stenosis, laminectomies, examining athletes presenting with pain, to assist in surgical planning, evaluating atlanto-axial rotatory fixation, examining the effects of cervical collars, characterizing joint disorders in the cervical spine, studying degenerative disease of the cervical spine, and determining the effects of occipitalization and odontoid hypoplasia on spinal motion.

In addition to the studies cited, applications for fluoroscopy in chiropractic have been reported in chiropractic trade publications, indexed peer reviewed literature, and presented at chiropractic symposia. Gillet, Henderson, Dorman and Howe used fluoroscopy to study cervical spine kinetics. Shippel and Robinson described a case where fluoroscopy and magnetic resonance imaging were used to evaluate cervical spine instability. Leung used fluoroscopy to evaluate the cervical spine and concluded, "Cineradiography has been found to be the method of examination that conveys most functional abnormalities. The diagnostic value of cineradiography is substantiated. The effect of chiropractic adjustment in removal of cervical fixations was proven with cineradiography."

Chiropractors Foreman and Croft in their textbook Whiplash Injuries state, "This motion study of the spine may be quite useful in detecting abnormal biomechanics secondary to ligamentous damage that may be unappreciated with plain film radiography." Cineradiography or fluorovideoradiography plays an important role in the diagnosis of aberrant spinal biomechanics that may be secondary to chronic muscle contracture, scar tissue formation, or ligamentous instability."

Antos, Robinson, Keating and Jacobs presented the results of an interexaminer reliability study of cinefluoroscopic detection of fixation in the mid-cervical spine. Two examiners reviewed fifty videotapes of fluoroscopic examinations of the cervical spine. The examiners achieved 84% agreement for the presence of fixation, 96% agreement for the absence of fixation, and 93% total agreement. The Kappa value was .80 ($p < .0001$). Only the C4/C5 level was examined. The authors concluded, "The current data indicate that VF determination of fixation in the cervical spine is a reliable procedure."

Other chiropractic authors have described applications for fluoroscopy. Taylor and Skippings used the procedure to study paradoxical motion of the atlas in flexion. Betge described applications for fluoroscopy in the analysis of dysfunctions of the cervical spine. Masters and Mertz both used fluoroscopy to evaluate spinal motion. Robinson and Sweat have also published articles concerning chiropractic applications for fluoroscopy.

In addition to patient evaluation studies, fluoroscopy has also been used to study normal motion in the spine. Bronfort and Jochumsen used cineradiography to evaluate intermediate stages and extremes of intervertebral motion in the lumbar spine. Fielding and Howe described normal motion of the cervical spine based on cineradiographic examinations.

Persons critical of the use of videofluoroscopy to evaluate joint motion, particularly in the cervical spine, appear to be applying a more burdensome standard than that required of other imaging techniques. It is suggested that such critics consider the following:

1. Videofluoroscopy is not a new procedure. Fluoroscopic studies of the spine have been reported in the medical literature for several decades.

Numerous observational and case studies have been published in indexed peer reviewed journals.

1. At least one chiropractic study concluded that fluoroscopy was a reliable technique for evaluating fixation in the mid-cervical spine.

Many investigators have reported that fluoroscopic studies revealed abnormalities (some potentially lethal) that could not be appreciated on plain films.

An evaluation of diagnostic procedures for spinal disorders published in Spine concluded that cineradiology's usefulness - in conditions where radicular compression was presumed, spinal stenosis was confirmed, and in symptomatic post-surgical patients, has been demonstrated in non-randomized controlled trials. The same report noted that it was common practice to use the technique in cases of localized spinal pain and pain radiating to an extremity.

Diagnostic imaging is by its very nature an "observational" procedure requiring a skilled examiner to interpret the findings.

Imaging studies are one part of the data set used by a clinician to make a diagnosis and formulate a care plan. The findings of any imaging study must be integrated with the history, physical, and laboratory findings in a given case. Thus the claim that fluoroscopy is not "...a diagnostic entity unto itself" could be applied to any imaging technique.

THE ISSUE OF RADIATION EXPOSURE

Critics of videofluoroscopy frequently express concern for the radiation exposure produced by the procedure. According to Robinson, 60 seconds of videofluoroscopy is equivalent to 2 to 7 plain films. Pierce states that videofluoroscopy of the cervical spine can be performed at 1/4 MA. This would result in radiation levels even lower than those reported by Robinson. Howe states that "The radiation dose to the patient is not significantly higher than that incurred in plain film studies."

The issue of radiation exposure is clouded by authors claiming that fluoroscopy is "...a functional study only..." and that "...it is quite possible to miss subtle pathology." The assumption is made that a full complement of plain films will be taken in addition to the fluoroscopic study. If, however, up to 60 seconds of low milliamperage fluoroscopy is substituted for the static flexion/extension views normally taken in a Davis series, the radiation burden to the patient will be roughly equivalent, and the potential diagnostic yield far greater. Even if fluoroscopy is used in addition to a full Davis series, the diagnostic yield may justify the exposure in cases where the plain films fail to demonstrate an abnormality which is suspected clinically.

INDICATIONS FOR VIDEOFLUOROSCOPY

Any technique involving exposure to ionizing radiation should be used judiciously. Several authors have suggested indications for videofluoroscopic studies. They include:

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.

TECHNICAL CONSIDERATIONS

For chiropractors employing videofluoroscopy:

1. Fluoroscopic studies should not be routinely employed. The decision to order a fluoroscopic study should be based on demonstrated clinical need.
2. All fluoroscopy should be performed with electronic image intensification.
3. The beam should be collimated to the smallest possible size which will demonstrate the area of clinical interest.
4. Gonad shielding should be employed when it will not obliterate the structures under examination.
5. The fluoroscopic image should be recorded on videotape or other appropriate medium to enable the chiropractor to review the study without requiring excessive repetition of a given movement.
6. "Beam on" time should be kept to the minimum necessary to characterize the abnormality.

Chiropractors performing videofluoroscopic studies should have training in fluoroscopic technique and interpretation.

Technical Considerations

1. Machine selection: General guidelines provide for the use of recently manufactured equipment which is capable of low dose image acquisition.
2. Factor selection: Optimum factors should be selected as per manufacturer's specifications.
3. Shielding: General guidelines provide for the use of shielding to eliminate patient dose over radiosensitive areas outside of the area in interest.

Analysis

Stress study similarity: Although similar to the analysis of plain film stress studies, which are generally taught in the chiropractic curriculum, the interpretation of videofluoroscopy should be done by a doctor trained in the specific analysis of this type of study.

Series

1. Adjunctive procedure: Videofluoroscopy should be used as an adjunctive procedure to plain film studies, and not as a replacement for those studies.
2. Repeat studies: Due to the dangers inherent in radiation exposure, repeat studies should only be used as clinically required.

15.2.1. **Rating:** Positive recommendation
 Strengths: E, L

C. Magnetic Resonance Imaging (MRI)

Provides information concerning both hard and soft tissue spinal structure in a single imaging format.

Clinical Necessity

MR imaging may be employed to visualize soft tissue structures (e.g., nerve roots) and hard tissue structures (e.g., bone) in a single imaging format.

Technical Consideration

1. Machine selection: Due to the great expense associated with MR imaging units, it is unlikely that they will be purchased by private practitioners.
2. Factor selection: Optimum factors should be selected as per manufacturer's specifications.
3. Safety: At this time there are no known detrimental effects associated with this procedure, taking into account manufacturer's published contraindications.

Analysis

MR image interpretation has only recently been introduced in the chiropractic college curriculum; for this reason, interpretation should be done by a doctor trained in the specific analysis of this type of study.

Series

Due primarily to the high cost per image, MR image studies should be limited to those cases in which standard analytical measures are inadequate.

15.3.1. **Rating:** Discretionary
 Strength: E, L

D. Computerized Tomography (CT)

Clinical Necessity

1. CT imaging may be employed to visualize spinal structures in planes other than those available through plain film radiography.

2. Current usage provides information concerning pathological states. However, it is possible to obtain information concerning the misalignment, foraminal alteration and nerve impingement, components of the classically defined vertebral subluxation and other malpositioned articulations and structures, through the use of CT images.

Technical Consideration

Machine selection: Due to the expense associated with CT imaging units, it is unlikely that they will be purchased by private practitioners.

2. Factor selection: Optimum factors should be selected as per manufacturer's specifications.

Safety: Since CT is an x-ray imaging modality, patient protection protocols associated with all ionizing radiation imaging equipment apply.

Analysis

CT image interpretation is taught to a small degree in the chiropractic college curriculum; for this reason, primary interpretation of these images should be done by a doctor specifically trained in the analysis of this type of study.

Series

Due to the concern for radiation safety, CT image studies should be limited to those cases in which standard analytical measures are inadequate.

15.4.1. **Rating:** Discretionary
Strength: E

E. Ultrasonography

Ultrasonography may be used to visualize soft tissue structures of the musculoskeletal system. It is an established procedure for the evaluation of extraspinal soft tissues structures, such as the thyroid gland and the abdominal aorta. In spine imaging, it has been used to measure the central canal to determine stenosis. Other spinal applications are under investigation.

Clinical Necessity

Investigational, ultrasonography has been used for visualizing soft tissue structures of the musculoskeletal system. This use may ultimately provide information which would be germane to chiropractic practice.

15.5.1. **Rating:** Investigational
Strength: E

F. Contrast studies

A doctor of chiropractic may refer a patient for contrast studies when clinically indicated.

15.6.1. **Rating:** Discretionary

G. Radioisotope scanning (Nuclear medicine)

be used to assess the biomechanical component of the vertebral subluxation and other malpositioned articulations and structures complex, as well as determine the presence of traumatic injuries, pathology, and developmental variants which may affect patient care. This includes spinal and extraspinal structures. Procedures which involve the use of ionizing radiation should be employed only when clinical need is established by the history and clinical assessment. The potential benefits of a proposed imaging procedure should be carefully weighed against the risks and cost. The most cost effective procedure which will provide the information needed should be employed whenever possible.

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VIII. TABLES

TABLE 1

Technical Factors for the Production of Quality Radiographs

- Collimation. Maximum collimation of the primary beam is used to expose only necessary areas and to exclude the eyes, breasts, and gonads whenever possible.
- Filtration. Density equalizing filtration is used to minimize excess exposure to thinner body parts.
- c) Lead Shielding. The breasts and gonads (male and female) are adequately protected with lead shields whenever possible.
 - d) P-A Projection. The posterior-to-anterior projection is employed whenever possible to further reduce radiation exposure to the breast, eye, and thyroid.
 - e) Rare-earth Screens. Rare-earth screens with matching film of the same spectral sensitivity and in the 800-1200 speed category is used.
 - f) Focal-Film Distance. FFDs of less than or equal to 72 are commonly used.
 - g) High kV. Exposures frequently greater than 90kV are used to reduce radiation exposure.
 - h) Adequate Grid. Use of a 12:1 grid allows higher kV values to be employed and is optimal for scatter absorption in the 90-100 kV range. However, a 10:1 grid is acceptable.
 - i) Technical Details. Careful attention to radiographic and darkroom procedures is employed to minimize retake examinations.