Educational Manual for Evidence-Based Chiropractic

Chapter 2

Diagnostic Imaging

Acknowledgements

We wish to acknowledge the hard work and expertise of the volunteers who comprised the steering committee, the seed panels that produced the seed statements, the nominal and Delphi panels who refined these statements, and the facilitators who conducted the consensus process. In addition we wish to thank the efforts of Meridel Gatterman who has served as process consultant, process manager, and compiler of the manuscript, and Kelly Bird and Dave McTeague who have edited the final copy.

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DIAGNOSTIC IMAGING

INTRODUCTION

The fundamental purpose of diagnostic imaging is to provide information to assist in the development of a diagnosis or otherwise impact the treatment plan. It is the responsibility of the chiropractic physician to keep abreast of advancements in diagnostic imaging. The chiropractic physician must make imaging decisions based on what is best for the patient.[1] This chapter presents current knowledge regarding the utilization of diagnostic imaging in the assessment of chiropractic patients.

APPROPRIATE UTILIZATION OF RADIOGRAPHIC STUDIES

While diagnostic-imaging procedures may be vital to diagnosis and case management, the decision to utilize any diagnostic imaging procedure should be based on a demonstrated need (i.e. clinical necessity) following an adequate case history and physical examination.[2]

Once radiographs have been obtained, it is required[3] that a report of the findings be recorded and placed in the patient's permanent record. It is the responsibility of the clinician to ensure that all radiographs are evaluated for pathologic and biomechanical information. All radiographic reports will include the patient’s name, age, sex, date of examination and report, and area of study and views. A narrative of radiographic findings, and impressions should be included.

The following discussion is designed to assist in the plain film radiographic decision-making process. The guidelines are divided into categories as shown in Table 1. These categories include: clinical indicators, structural and functional abnormalities, other indicators, and inappropriate use of x-rays. All relevant clinical and historical information needs to be considered.[4-39] The practitioner's clinical judgment will be the basis for determining whether to take radiographs or not. [40]

CLINICAL INDICATIONS

Table 1: Guidelines for Chiropractic Utilization of Radiographic Studies

- History of malignancy (with unexplained new symptoms) [4,5,6,7,11,12, 17, 19, 29]
- Significant trauma, recent trauma, repetitive trauma with significant clinical findings[4,5,6,7,12,13,14,15,16,17,18, 19]
- Old trauma in the area of complaint [3]
- Suspected fractures[5,10,18]
- Clinically significant neurologic signs and symptoms [4,5,6,7,13,14,15,16,19,29]
- Unexplained weight loss [4,5,6,7,14,17,19, 29]
- Unrelenting night pain [6, 17, 35]
- Pain unrelieved by recumbency [6,7,29, 38]
- Suspicion or history of inflammatory arthritis with change in symptoms [4,5,11,13,14,31]
- Known or suspected bone density loss [6,7,12]
- Palpable mass [5]
- Substance abuse [4,5,7,14]

- Prolonged corticosteroid use [4,5,7,14,17]
- Fever of unknown origin (>100° F) [4,5,7,14,17]
- Suspected infection [5,6,7,11,29]
- Abnormal laboratory finding (Erythrocyte Sedimentation Rate [ESR], White Blood Cell Count [WBC], etc.) [5,6,7,11,17]
- Recent surgery or invasive procedure related to chief complaint [5, 17]
- Failure to improve without prior radiography [4,5,6,14,17]
- Patients over 50 years of age are at greater risk of having significant pathologies[4,5,7,12,14,17,19,29,32]

Identification of Structural or Functional Abnormalities

- Scoliosis or deformity [5,17,20,21,30]
- Congenital anomaly [5,13,27]
- Surgical history at area of chief complaint [5,6,17,22]
- Postural abnormalities [17,]
- Hyper/hypomobility [23,24,36]
- Aberrant motion[32]

Other Indicators

- Suspected physical abuse [28]
- Environmental exposure to toxic or infectious agents [17]
- Recent immigration or foreign travel [17]
- Medicolegal implications when combined with clinical indicators[4,17,25]

Inappropriate use of x-rays

- Pregnancy - unless the patient's symptoms are of such significance that failure to x-ray would result in a substantial health risk to the mother [8,9]
- Financial gain [4, 17, 33]
- Patient education [4, 17]
- Routine (habitual) screening procedure [4, 17, 26, 33]
- Research without sanctioned review-board approval [34]
- Unnecessary duplication of services
- Routine pre-employment screening [17]
- Inadequate equipment to produce a diagnostic radiograph [3,5,10,17]
- Routine discharge radiographs [17,33]
- Non-licensed operator [3, 17]

IMAGING MODALITIES

There are a number of imaging modalities available to the chiropractic physician to utilize in the diagnostic work-up and treatment of patients. The following will be a discussion of those modalities including plain film radiography, tomography, fluoroscopy, videofluoroscopy, computed tomography (CT), magnetic resonance (MR) imaging, radionuclide imaging (bone scan), myelography, DEXA, PET, and ultrasound.

Plain Film Radiography

The use of plain film radiography in the chiropractic profession began in 1910.[36] It was initially used as a research tool and later as the imaging modality of choice for diagnosis of pathology as well as evaluation of postural and biomechanical integrities of the spinal column and pelvis. Use has expanded to include the appendicular skeleton.

Plain films offer the doctor insight into pathology, indications and contraindications for chiropractic adjustment, as well as postural and biomechanical alterations.[5] The risk of exposure to ionizing radiation mandates that a thorough history and examination be performed prior to the decision to utilize these procedures.

AP and lateral radiographs of the skeleton are the most common imaging procedure used in the chiropractic office. Additional views to the minimum diagnostic series include oblique views, angulated spot views, and dynamic stress studies. Oblique projections are essential in evaluating the facet joints of the cervical and lumbar spine as well as the intervertebral foramina (IVF) in the cervical spine. In the appendicular skeleton, oblique projections more fully demonstrate complex anatomy. Angulated projections are helpful in confirming or denying the presence of osseous versus soft tissue lesions. The sacroiliac joints are more clearly demonstrated on the angulated projection than on any other study.[37] Dynamic stress views include flexion/extension and lateral bending of the cervical and lumbar spine. These studies reveal information related to the end range of motion.[38] Stress radiography is also utilized to evaluate injured joints of the appendicular skeleton.

Soft Tissue Radiography

Soft tissue radiographs, chest and abdomen, are also utilized by the chiropractic physician. These types of studies may require specialized equipment i.e. film, screens, and grids to produce high quality radiographs. As with all radiographic procedures it is essential to obtain the highest quality radiographs when performing these procedures. Radiographs of soft tissues are strictly taken to evaluate for pathology. Poor quality radiographs reduce the likelihood that abnormalities will be identified.

In addition to plain film radiography of the abdomen, contrast studies of the digestive tract, barium swallow and enema, may be utilized by the chiropractic physician. Specialized equipment, i.e. fluoroscope, is needed to insure proper exposure and to produce superior quality radiographs. The images of the procedure must be videotaped. Initial evaluation of these procedures should be done in real time. Special training and experience are required to perform and interpret contrast studies.

Minimal Diagnostic Radiographic Series

It is accepted within the healthcare community that a minimum series of diagnostic radiographs are needed to evaluate each region of interest. As a general rule two views 90° to each other should be obtained. Some areas require additional views as an essential part of the minimal diagnostic series. The following tables represent the accepted standards.

Table 2: Minimum Standard Views for the Axial Skeleton, Chest, and Abdomen

AREA	AP	LATERAL	OBLIQUE	APOM	PA	ANGULATED
CERVICAL[39]	X	X		X		
THORACIC[40]	X	X				
*LUMBAR[41]	X	X				
PELVIS	X					
SACRUM/COCCYX	X	X				
STERNUM		X	X			
CLAVICLE	X					X
RIBS	X		X			
†SKULL	PA Caldwell	X				
CHEST (Full Inspiration)[42]		LEFT			UPRIGHT	
ABDOMEN	X					

*Lumbar spots may be needed, dependent upon the ability to visualize the L5-S1 region. Lateral spot or AP angulated spot radiographs should be considered after evaluation of the AP and lateral.

†To rule out pathology plain radiographs of the skull should only be taken as part of a study that includes computed tomography or MRI.[43]

Table 3: Minimum Standard Views for the Extremities**

AREA	VIEWS
ACROMIOCLAVICULAR JOINT[44]	Bilateral AP
SHOULDER	Internal and external rotation
ELBOW	AP and Lateral
WRIST	Dorsopalmar, dorsal oblique, and lateral
HAND	Dorsopalmar, dorsal oblique, and lateral
FINGERS	Dorsopalmar, dorsal oblique, and lateral
HIP	AP and frog leg lateral
KNEE	AP and lateral
PATELLA	AP, lateral, and sunrise
ANKLE	AP, medial oblique, and lateral
CALCANEUS	Axial and lateral
FOOT	AP, medial oblique, and lateral
TOES	AP, medial oblique, and lateral
LONG BONES	AP and lateral
TEMPOROMANDIBULAR JOINT	Lateral (TM joint is better evaluated with advanced imaging – MRI)

**Complete extremity series are dependent upon patient presentation and findings on initial radiographs.

NEUROMUSCULOSKELTAL SPECIAL IMAGING PROCEDURES

The choice of an appropriate imaging modality is a case specific process. A given patient may have specific needs or limitations that affect choices. The exact nature and degree of the pathology suspected affects imaging choices. These factors and the continuing development of imaging protocols make consultation with a radiologist valuable. The information provided here is intended as a general guide.[15,46-58]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a valuable diagnostic tool in neuromusculoskeletal imaging. Sectional images can be obtained through all body areas in axial (transverse), sagittal and coronal planes, or at oblique angles for smaller anatomical areas. No ionizing radiation is produced with MRI and risks to appropriately chosen patients have not been identified. Patients with pacemakers, some aneurysm clips, metallic foreign bodies, and other ferromagnetic artifacts are not appropriate candidates for MRI.

In general, MRI images tissues based on their hydrogen atom content, reflecting total quantity and molecular bonds. Therefore, both free and intracellular water, and fat produce the majority of the MRI "signal" which creates the image. MRI is an excellent procedure for imaging soft tissues of the body including the brain, spinal cord and cerebrospinal fluid, intervertebral discs, articular cartilage, muscles, tendons, ligaments, menisci, and most organs. MRI does not image cortical and trabecular bone though changes in the surrounding marrow can be diagnostic for many osseous pathologies.[51]

MRI is rarely used as the initial imaging procedure. In many cases, MRI will provide additional information after evaluation of plain film radiographs. MRI may be used as the initial study in cases of significant or rapidly progressing neurologic changes, especially those that indicate central nervous system **(**CNS**)** pathology. MRI is also useful as a follow-up imaging procedure after surgical treatment for IVD herniation and neoplasm. [51]

Computed Tomography

Computed tomography (CT) combines the imaging physics of plain film x-ray with the advantages of sectional imaging**.** Like plain film, CT produces its images through the interaction of x-ray photons with the tissues of the body, and is quite valuable in imaging osseous structures .[15] CT also carries the same consideration of the potential harmful effects of ionizing radiation. The radiation dose should be kept as low as possible without losing diagnostic information and the risk-benefit ratio carefully weighed. Pathologies containing calcium densities may also be evaluated with CT. Some soft tissues, particularly of the chest and abdomen are best imaged with CT due to limitations of MRI in those areas.

Previously known as the CAT (computed axial tomography) scan, it is important to remember that primary or direct images are obtained in the axial plane. Sagittal and coronal reconstructions can be formed with the data obtained in the axial plane, but some extrapolation is done by the computer with a resultant loss of detail. Three-dimensional CT offers limited diagnostic information and is used primarily as a surgical planning tool.

Computed tomography is used extensively, with and without intravenous contrast agents, for chest and abdomen examinations. It is superior to MRI in most scenarios for the chest and abdomen since the motion artifacts produced by heart contractions and bowel peristalsis may interfere with the acquisition of MR images. Plain film radiographs, as scout films, will often be used for preliminary examination of the chest and abdomen before CT imaging.

CT provides detailed evaluation of fractures. This is particularly useful in unusually shaped bones or areas difficult to image with plain film such as the pelvis, craniovertebral junction, posterior elements of the spine, and ankle. Computed tomography may be combined with arthrography when the differential list includes cartilaginous and bony abnormalities or when MRI is inconclusive, such as some cases of glenoid labrum tear. CT evaluation in the musculoskeletal system typically follows radiographic examination.

Computed tomography is also used extensively, though less than MRI, in evaluation of the spine, spinal canal, and intervertebral discs. CT is superior to MRI in detailing significant osseous changes, but MRI is usually more valuable in evaluating the impact on neurologic structures. Myelography can improve the ability of CT to evaluate neurologic structures, especially the thecal sac. In some cases, both procedures will be used to reach an accurate diagnosis and provide information for surgical planning. In cases where MRI is not available or not appropriate, CT, with or without myelography, is typically the imaging procedure of choice.[51]

CT is also used to evaluate head trauma injuries where fracture and acute intracranial bleed are suspected

Radionuclide Imaging

Radionuclide imaging of bone (bone scan) involves the intravenous administration of a radionuclide tagged to a phosphate analog, which is incorporated in the hydroxyapatite crystal of bone. Gamma rays emitted by the radionuclide are then detected quantitatively to produce an image. The image produced reflects blood flow and areas of increased bone production. Bone scan is much more sensitive than plain film for detecting osseous abnormalities but is distinctly nonspecific and would not be used as the only imaging procedure. A bone scan is typically used when the presence or the location of osseous pathology is questioned. Since almost all pathologies of bone lead to some reactive bone growth, bone scan may be applicable in a wide variety of suspected pathologies. It is most commonly used in the detection of radiographically occult stress fractures, neoplasms, and infection. It is used extensively in the evaluation of skeletal metastasis since the entire skeleton can be imaged at once.[15,51]

Single photon emission computerized tomography (SPECT) is a very useful method for displaying multiple planes of radionuclide activity. SPECT is especially useful to identify small areas of osseous pathology, particularly in the spine.

Radionuclide scans are also available for many organs. These scans may allow some degree of visualization to evaluate the size and location of organs. They are most useful in their ability to indicate the functional quality of the tissue in question.

Diagnostic Ultrasound

Diagnostic ultrasound (US) is an imaging procedure that relies on the reflection or transmission of sound waves by body tissues for producing images. The added capabilities of Doppler ultrasound allows for the quantification of flow rates in given structures, like arteries. Among the most significant advantages of US are availability, low cost, noninvasiveness, and lack of known harmful effects. This procedure is used frequently in abdominal imaging where it is capable of determining organ size, organ masses, and in distinguishing between cystic, solid, and complex masses. It is typically the first imaging procedure chosen for thyroid abnormalities and can provide useful information in breast imaging. Diagnostic ultrasound is also increasing in use for musculoskeletal imaging and it is capable of detecting tears or hypertrophy in some of the commonly injured and more superficial soft tissue structures. Superficial masses may also be initially evaluated by ultrasound.

The large quantity of cartilage relative to bone in the pediatric skeleton, especially the very young, lends itself to evaluation by ultrasound. Diagnostic ultrasound of the adult spine is controversial due to a lack of consensus on normal versus abnormal findings. [51]

Videofluoroscopy

Videofluoroscopy (VF) is a modality that enables clinicians to view dynamic, real-time imaging of anatomy and function. VF is also a diagnostic test that can reliably record dynamic function of joints and their range of motion. [1], [2], [3], [4], [5] The role of VF has been well established in interventional radiology and in the evaluation of neuromusculoskeletal, gastrointestinal, myelographic, and other studies requiring the injection of contrast material.

VF like other advanced imaging modalities is not typically utilized as an initial imaging procedure. It may be used as a follow-up to demonstrate abnormal joint mobility that is suspected clinically but not adequately substantiated by other diagnostic studies. [6], [7], [8] The value of VF, by comparison to static imaging modalities, is its ability to visualize the entire range and character of joint motion. [3], [4], [6], [9], [10], [11] The ability of VF to absolutely define segmental range of motion and the therapeutic significance of direct visualization of spinal dynamic function needs further investigation. [5]

Practitioners utilizing VF must document clinical justification and be cognizant of its contraindications, and limitations. [12], [13], [14], [15], [16] Specialized training is needed to adequately interpret the images acquired. Operators of this equipment must be knowledgeable in the basic concepts of radiobiology and fluoroscopy systems. [4]

Table 4: Comparison of Imaging Procedures

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
Muscle or tendon injury of extremities	Minimal use: May identify secondary effects, such as subluxation, gross disruption of Achilles' and quadriceps tendons.	No routine use; may add info regarding associated osseous structures	Ideal imaging in most cases	No routine use	Best imaging choice in some cases, particularly where structure is superficial (rotator cuff, Achilles' tendon, quadriceps tendon, many muscles)	Imaging often not required; most useful in evaluating for suspected instability and the need for surgery
Ligamentous injury of extremities	May identify secondary effects such as subluxation stress studies may be diagnostic	No routine use; may add info regarding associated osseous structures	Ideal imaging in most cases	No routine use	Limited, specific applications	Imaging often not required; most useful in evaluating for instability and need for surgery
Fibrocartilage injury	Offers little or no diagnostic information	Offers little or no diagnostic information	Imaging of choice in most cases	No routine use	No routine use	Arthroscopy may be the most appropriate procedure
Muscle, tendon or ligament injury of spine [15]	May identify secondary effects such as subluxation, especially on stress studies.	No routine use; May add info regarding associated osseous structures	No routine use; gross soft tissue disruptions may be appreciated	No routine use	Limited specific applications	

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
IVD pathology (excluding routine degenerative change) [15,46-48]	Limited information; may be used to rule out other diagnoses	Provides some imaging of disc , herniations; addition of myelography provides some information of effect on adjacent neural structures	Best imaging choice, provides anatomical and physiological information and the effect on adjacent neural structures without added contrast	No routine use	No routine use	Incidental bulges and herniations may have no clinical significance. Discogram may be useful to identify symptomatic anular tears.
Stenosis: central canal, lateral recess, intervertebral foramen [59,50]	Limited value in evaluating presence or extent of stenosis; often first imaging choice to evaluate gross osseous changes	Excellent for determining and quantifying osseous and some soft tissue causes of stenosis; addition of myelography allows evaluation of effect on neural structures	Often imaging of choice due to less invasive nature, lower risks. Excellent for determining soft tissue causes of stenosis and for determining effect on neural structures; less useful in evaluating osseous impact	No routine use	No routine use	
Post-surgical spine, new or increased symptoms [15]	Appropriate for initial evaluation; stress views may be useful in evaluating fusion	May be useful in evaluating osseous abnormalities; surgical changes may make interpretation difficult	Appropriate for evaluating effect on neurologic structures; with contrast can identify scar tissue	May be useful in detecting pseudoarthrosis	No routine use	

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
Fracture, acute, extremity (1)	Initial imaging of choice; often only imaging required	Useful for complex fractures, areas of complex anatomy (elbow, ankle, etc.); appropriate for evaluation of intra-articular extent of fracture	Excellent for identifying bone contusions and subtle fractures may be used following CT to determine effect on neurologic structures	Useful when clinical suspicion of fracture is high and radiographs are negative or inconclusive	No routine use	
Fracture, acute, spine [7,51]	Initial imaging of choice; may require follow-up with CT or MRI	Excellent for evaluating spinal fracture; appropriate when suspicion of spinal fracture is high and radiographs are negative or inconclusive; sagittal and coronal reconstructions may be helpful; useful in areas of complex anatomy (crabiovertebral and pelvis, etc.)	Appropriate for spinal injury with positive neurologic findings; Excellent for evaluating effect on neural structures; offers little fracture detail; can differentiate simple compression fracture from pathologic fracture	May be used when clinical suspicion of fracture is high and radiographs are negative; SPECT imaging may be required	No routine use	
Fracture, stress [49]	Initial imaging of choice; many will be radiographically	May be used to determine extent; not usually required; may be	Sensitive to early changes; may be difficult to differentiate	Appropriate for detection of radiographically occult, clinically	No routine use	

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
	occult, especially in early stages	useful for pars interarticularis	stress fracture from other pathologies	suspected stress fracture; may require SPECT imaging, especially in the spine and other areas of complex osseous anatomy		
Dislocation	Most appropriate initial imaging	Useful if radiographic findings questionable; may be used for additional detail, especially to detect associated fracture	May be useful in detailing associated soft tissue injuries and/or effect on adjacent neurovascular structures	No routine use	No routine use	
Articular cartilage pathology [52]	Depicts general cartilage loss; may show calcinosis secondary to crystal deposition; not effective for focal defects	No routine use	Diagnostic in most cases; intra-articular contrast (MRI-arthrogram) may improve sensitivity	No routine use	No routine use	
Suspected intra-articular body	Most appropriate initial imaging; may not provide information with uncalcified, unossified	With arthrography, can provide diagnostic information	Can provide diagnostic information; excellent for osteochondritis dessicans [15]	No routine use	No routine use	Arthroscopy preferred if clinical suspicion is high

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
	cartilagenous bodies					
Congenital malformation [15]	Initial imaging of choice	May provide detail in complex osseous malformation	May provide valuable information regarding associated soft tissue or neural abnormalities	No routine use	No routine use	
Biomechanical aberration	Appropriate for initial imaging; stress views may be required; fluoroscopy may add information	May be useful as follow-up to radiographically identified abnormalities	May be useful; stress studies may be useful	No routine use	No routine use	
Degenerative joint disease [53,54]	Imaging of choice	Rarely provides additional information; some complex or surgical cases may benefit	May be useful in evaluating some complications, such as stenosis	Can identify sites of involvement, but very non-specific	No routine use	
Inflammatory arthritis [55,56]	Imaging of choice	Rarely provides additional information	Can detect some changes earlier than plain film	No routine use	No routine use	
Crystal deposition disease [57,58]	Imaging of choice	More sensitive to calcium deposition, but rarely provides additional information	Can detect articular cartilage involvement	No routine use	No routine use	

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
Infection [7,15]	Initial imaging of choice; radiographic latent period from several days to several weeks	May be useful as follow-up to radiographically identified abnormalities	Very sensitive; no significant latent period; useful in radiographically occult cases and to determine extent of involvement	Much more sensitive than plain film; non-specific; useful in cases of high clinical suspicion and negative radiographs	No routine use	
Neoplasm, osseous [7]	Initial imaging of choice	May be useful as follow-up to radiographically identified abnormalities or in areas of complex anatomy	Very sensitive; may provide useful histologic information; useful in radiographically occult cases and to determine extent of involvement. Procedure of choice for multiple myeloma	Much more sensitive than plain film; non-specific; useful in cases of high clinical suspicion and negative radiographs, and to determine the extent of skeletal metastasis		Metastasis evaluation requires very specific Metastasis evaluation requires very specific protocols based on a number of patient variables
Neoplasm, soft tissue [59]	Initial imaging of choice, but frequently non-diagnostic; use soft-tissue technique	Useful in evaluating tumors containing fat, calcium or bone; useful in determining osseous involvement	Most appropriate imaging	No routine use	May be useful in determining some tumor characteristics and effect on adjacent structures	P.E.T. useful for detecting breast, colon and brain neoplasms

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
Avascular necrosis	Initial imaging of choice; significant radiographic latent period	No routine use	Most appropriate in cases of high clinical suspicion and negative radiographs; demonstrates extent of involvement [15]	Sensitive, but not specific; appropriate in cases of high clinical suspicion and negative radiographs	No routine use	
Metabolic disease	Secondary skeletal changes may be identified and monitored	Not likely to add significant information	Some complications, changes may be identified	May provide information regarding sites of skeletal involvement	No routine use	
Head injury	Not likely to provide significant information	Imaging of choice in suspected skull fracture; provides significant information regarding acute brain trauma	Provides significant information regarding brain trauma; CT may be more appropriate in early stages	No routine use	No routine use	
Chronic sinus disease	Appropriate for initial evaluation; not as sensitive or specific as CT	Most appropriate imaging; initial imaging in most cases	May be used as follow-up to CT findings in unusual cases	No routine use	No routine use	
GI disease	Abdomen plain film does not provide adequate information in most scenarios; used as initial	Provides best imaging of many organs; frequently used with addition of	Useful for evaluation of some organs; presence of gas and intestinal motility often	Scans for specific organs can be useful	Frequently used in evaluation of abdominal disease; especially useful for solid organs	

PATHOLOGY	PLAIN FILM	COMPUTED TOMOGRAPHY	MRI	RADIONUCLIDE STUDY	ULTRASOUND	CLINICAL CONSIDERATIONS
	evaluation for suspected acute obstruction or perforation; barium studies may be diagnostic	barium	provides for poor imaging		and cystic abnormalities	
GU disease	Frequently used as initial study, but usually requires additional imaging; addition of contrast often required	Often provides best imaging; usually includes contrast agent	Frequently useful; may not provide adequate imaging of some areas	No routine use	Frequently used for evaluation of kidney and bladder disease	

IMAGING OF BIOMECHANICAL ABNORMALITIES

Chiropractic radiographic analysis that includes appropriate views, when combined with clinical findings, is intended to provide a better understanding of the patient's condition[60]. High quality radiographic images are essential to rule out pathology and evaluate structural alignment[61]. When radiographs are part of a biomechanical analysis it is paramount to evaluate images for pathologies that may weaken bony architecture, requiring modification of therapy[62,63]. Biomechanical analysis is used to determine misalignment, postural and motion abnormalities, and to guide manipulation.

Many radiographic lines, angles, and measurements have been demonstrated to be reliable indicators of postural and biomechanical abnormalities. [32,37]

Spinal Radiographic Analysis

Most chiropractic methods of radiographic analysis have stressed the importance of assessing the patient in the upright, weight-bearing position. This allows for both full spine and regional postural evaluation. Specific consideration is given to the identification of abnormal spinal curves, that may compromise efficient biomechanical function. Studies that evaluate the reliability, validity and clinical relevance of radiographic line drawing have produced conflicting evidence.[32,37]

Reliability

Reliability is the repeatability of a measurement and indicates consistency and precision when a procedure is done by different examiners and at multiple times.[14] Factors that influence the reliability of spinal radiographic analysis include: anatomic variants, positioning of patient and x-ray equipment. In addition to these and other potential sources of systematic error, random measurement error adversely affects the reliability of measurement methods. While inter-examiner reliability of the actual marking of x-rays has been demonstrated [64-68], the reliability of the entire procedure has not been established. [14] Reliability does not establish the clinical relevance or validity of measurement procedures.

Validity and Clinical Efficacy

Validity refers to how accurately an assessment procedure measures, identifies or predicts the true state of the patient.[69] While construct validity (a measure of the theoretical concept of x-ray line marking) has been evaluated,[68] the predictive validity (the clinical relevance of x-ray line marking, i.e. can it identify current spine problems, predict future occurrences, or measure resolution) has not been established through well-designed clinical trials.[70] Predictive validity is crucial; it is far more relevant than construct validity or reliability tests in establishing the clinical efficacy of assessment procedures

Functional Radiographic Analysis

Functional radiographs are practical tools for the evaluation of spinal segmental motion. Since Hviid[71] in 1963, chiropractors including Sandoz,[72] Anderson,[73] Conley,[74] West,[73] Grice[75] and Henderson [76] have advocated cervical templating techniques to determine hypomobility, hypermobility and instability of spinal motion segments. Functional radiographs may be used to evaluate the segmental range of motion by comparing the neutral position to the end range of movement in either the sagittal or coronal planes. Medical investigators, including Penning[77] and Dvorak,[38] have established normative values for gross segmental flexion and extension without reference to the neutral lateral view. However, clinical information may be lost when the information from the neutral position is not included in the assessment.

The key to accurately evaluating motion on functional spinal radiographs is precise standards of patient positioning.[60] Meticulous attention to the details of positioning cannot be overemphasized if the information obtained from the resultant radiographs is to be considered a reliable assessment of that particular patient's function.[78] Functional radiographic studies have traditionally been performed with active movement by the patient. Dvorak et al[38] emphasized the value of obtaining functional radiographic studies of the cervical spine both actively and passively. While they claim that many more hypermobile segments are discovered on the passive stress studies[38] the application of force at the end of active range of motion risks injury to the patient. These systems of functional radiographic analysis may be of clinical value to the doctor of chiropractic who provides spinal manipulation/adjustments to specific levels of segmental dysfunction.[32] The reliability[38] and clinical validation[79] of cervical flexion extension studies have been demonstrated.

Full Spine Radiography

Depending on history and clinical findings, the need for full spine radiography is based on the clinical judgment of the doctor. The choice of sectional or full spine views is dependent on clinical necessity and the ability to produce diagnostic quality radiographs. AP/PA full spine radiographs are used for evaluation of pathology and biomechanical analysis. Single exposure, lateral full spine radiographs are not recommended.[63]

The use of full spine radiographs is of value when clinical findings indicate the involvement of multiple spinal levels .[63] Taylor[32] has noted the following circumstances in which the PA full spine radiograph may be preferred over sectional radiographs:

- cases in which clinical examination disclosed the need for radiography of several spinal sections;
- cases in which severe postural distortions are evident, scoliosis evaluation after clinical assessment;
- cases in which a mechanical problem in one spinal area adversely affects other regions;

- to specifically evaluate complex biomechanical or postural disorders of the spine and pelvis under weight bearing conditions.[32]

Full spine radiographs can be considered to be of diagnostic quality[80] with less radiation exposure to the patient compared to sectionals of the multiple levels involved This requires appropriate technology and technique with careful attention to exposure factors, film speed, and shielding.[78,81,82] The evaluation of suspected pathology may require sectional or spot views to attain better detail.[63]Analysis of full spine radiographs has been used to identify biomechanical faults, chiropractic subluxations and joint dysfunction.. There is a variety of line marking systems used to evaluate radiographs. The validity and reliability of the full spine analytical systems has been studied with mixed results.[63,83,84,85]

PATIENT SAFETY

Patient safety in diagnostic imaging encompasses a range of activities performed before, during and after the actual imaging exam. The primary goal of these efforts is to provide the most clinically significant information with the lowest possible risk and cost to the patient. [86,87,88] The following key areas should be addressed: patient education and informed consent (PARQ), patient comfort, selection criteria, radiation safety, image quality control, facilities maintenance and record keeping.

Patient Education and Informed Consent (PARQ)

The chiropractic physician should explain the diagnostic imaging procedures and follow up, the time and cost involved, risks and contraindications, and patient preparatory procedures. This should be done regardless of whether the treating physician will perform the imaging or order it from another facility. (See patient/doctor relationship chapter)

Patient Comfort

A clean, safe, comfortable environment should be provided for waiting, changing garments, securing personal items, and performing the imaging procedure. The privacy of the patient should be guarded during preparation for and execution of the exam, as well as with the storage of radiographs and reports.

Radiation Safety

The most important aspect of patient safety is to minimize the radiation dose to the patient. There is no known safe dose of ionizing radiation. Even the smallest dose can produce genetic damage. Diagnostic imaging doses do not typically produce clinical manifestations. The benefit to the patient must outweigh the risk.[88-92]As Low As Reasonably Achievable (ALARA): Efforts should be made in all areas of the imaging procedure to provide the lowest possible dose to the patient without compromising image quality. [90]

Patient Selection Criteria

The planned diagnostic imaging procedures must supply significant clinical information that cannot be otherwise determined. If the diagnosis, treatment or prognosis will not likely change based on imaging findings, the imaging is not appropriate. Every exposure, including post-treatment exposures and scanograms, must have clinical justification with adequate documentation consistent with the patient's case history. [93]

Chiropractic physicians are responsible for ordering necessary and appropriate imaging studies. More than one study may be indicated to fully evaluate a patient. Pre-existing x-ray studies should be accessed if possible. These may be repeated if timely access is not feasible, they are of poor quality or are not clinically relevant. Consultation with a radiologist may be helpful in determining which studies are most appropriate for a case.

Image Quality Control

Assurance of image quality and low patient dose is dependent on many equipment and procedure factors. Attention is required in the setup and maintenance of equipment as well as during the imaging procedures. [86,87,89,94]

The following factors are listed as a guide for evaluating and monitoring plain film quality as it relates to patient safety. These should be considered to assure the highest possible film quality and lowest possible patient dose.

Equipment

- Tables and film holders: stable, level, and plumb
- Control arm / tube holder: stable, locking mechanism for maintaining appropriate angle, markings for consistent and reproducible source image distance (SID)
- Collimation: accurate, centered, apparent on three sides
- X-ray tube and exposure controls: calibrated, current exposure charts
- Film/screen combinations: as fast as possible while maintaining adequate detail, screens clean and without defects, cassettes marked and without defects
- Markers: adequate to identify patient, anatomy, special procedures, proper placement
- Filters and shields: devices for reducing dose to sensitive tissues such as eye, thyroid gland, breast, and gonads should be available for frequently performed studies
- Processor: chemicals should be changed at prescribed intervals, processing temperature and speed consistently monitored
- Darkroom: film storage and handling should be safe from fogging factors

Technique

- Technique charts: current and appropriate to the equipment; charts used consistently, factors recorded
- Positioning: standard and consistent positioning; options in positioning that may reduce dose employed (PA for full-spine; anode-heel effect).[95,96] minimum diagnostic series to assure complete evaluation
- Patient prep: gown as appropriate, remove jewelry, dentures, other artifacts as appropriate
- Repeat films rates: monitored to identify problems

Facilities Maintenance

Equipment such as a floating tabletop, movable wall bucky, and the locking tube arm mechanism should be stable. Storage of chemicals should not pose a hazard to patients.

Facilities should allow for adequate performance of chosen procedures. Room size should accommodate the longer source-image distance (SID) required of projections such as the lateral cervical spine and PA and lateral chest. A horizontal surface should be available to accommodate certain extremity studies, lumbar imaging on larger patients, and patients with difficulty remaining immobile.[2] Referral may be necessary when facilities will not accommodate for special patient needs. Appropriate shielding should be utilized. Extremity and chest radiographs require specific film/screen combinations. Additional materials such as supports, weights and compression bands should be available. The patient should be referred to an appropriate facility if available equipment is not adequate to perform a chosen study.

Test and evaluation procedures are recommended at given intervals. [93,96] (See Appendix A.)

Record Keeping

Following production and processing of radiographs, films should be checked for proper identification. (See Appendix B.) A written report should be generated that includes identifying information, the study performed, pertinent findings and a clinical impression. Optimally one copy of this should be kept with the films in addition to a copy that should be placed in the patient's file. Films should be stored in an area that provides for patient privacy and has physically appropriate conditions to protect film quality.[86]

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APPENDIX A
Imaging Test/Evaluation Procedures[97]

The following test/evaluation procedures are recommended at the given intervals:

Daily (before use)

- Warm up processor (prescribed time)
- Check developer temperature
- Fill rinse tank
- Clean cross-over rollers
- Run and check "clean-up" film
- Warm up x-ray tube
- Visually inspect darkroom

Daily (end of use)

- Turn off processor
- Offset processor cover
- Drain rinse tank

Monthly

- Inspect film and chemical storage areas
- Inspect darkroom
- Check accuracy of built-in processor thermometer

Quarterly

- Evaluate retake rate, reasons
- Clean intensifying screens
- Inspect screens and cassettes

Semi-annually

- Test darkroom for light leaks
- Evaluate film fog from safelight
- Check film fixer retention
- Check collimator light field to radiation field
- Evaluate intensifying screen/film contact

- Sensitometry-densitometry

Annually (Most performed by service engineer)

- Check/calibrate kVp accuracy
- Check mAs reproducibility
- Check radiation dose reproducibility
- Evaluate filtration
- Check SID accuracy
- Check x-ray beam perpendicularity, bucky centering
- Evaluate focal spot size
- Check grid uniformity and alignment
- Check phototimer reproducibility
- Check exposure timer accuracy

Modified from: Guidelines for Establishing Radiographic Quality Assurance and Quality Control Programs," State of California; Continuous Quality Assurance and Quality Control Program.

APPENDIX B

Legal Requirements for taking X-rays in the State of Oregon[98]

The following changes were made to Chapter 811 administrative rules in November 2004 by the Oregon Board of Chiropractic Examiners. (New language is underlined, deleted language is struck through.)

Supervision

811-030-0011 Staff employees of a Doctor of Chiropractic may be directed to take X-rays of a patient if they are in possession of a permit issued by the State Board of Radiologic Technology, but this permit is limited only to the taking of X-rays. (ORS 684.155)

Scope of Radiography in the Chiropractic Practice

811-030-0020 (1) The radiographic diagnostic aspect of Chiropractic practice shall include all standard radiographic procedures that do not conflict with ORS 684.025.

(2) All radiographs shall be of diagnostic quality. Radiographic films are subject to review by the Board to determine quality. Poor quality radiographs may result in disciplinary action.

(3) X-ray is not to be used for therapeutic purposes.

(4) Fluoroscopy shall not be used as a substitute for an initial radiographic study and shall be used only with documented clinical justification. In order for anyone to operate a fluoroscopy unit they must be properly trained and they must have written documentation that shows that these requirements are met. (OAR 333-106-045)

(5) Use of radio-opaque substances for diagnostic X-ray, other than by mouth or rectum, is not permitted.

(6) Pregnant females shall not be radiographed unless the patient's symptoms are of such significance that the proper treatment of the patient might be jeopardized without the use of such radiographs.

(7) All critical parts, i.e. fetus, eyes, thyroid gland, breasts and gonads, beyond the area of primary examination shall be shielded. (684.155)

X-ray Departments, Equipment and Procedures

811-030-0030 (1) All X-ray departments, equipment and **procedures including fluoroscopy** shall be in compliance with the current rules and regulations of the Oregon State Health Division Radiation Control Section, including but not limited to, the physical design of the department, occupational exposure, collimation, shielding and exposure charts ~~and fluoroscopy~~.

(2) In addition:

(a) The patient shall be an adequate candidate for the radiographic or fluoroscopic procedure employed;

(b) The radiographic field shall be restricted to the area of clinical interest;

(c) Specialized views shall be used any time the area of clinical interest is not clearly visualized on a standard film;

(d) Every exposure, including post-treatment exposures, and scanograms, shall have clinical justification with adequate documentation consistent with the patient's case history;

(e) The operator shall maintain a record on each exposure of each patient containing the patient's name, the date, the operator's name or initials, the type of exposure and the radiation factors of time, mA, kVp and target film distance, including those exposures resulting in the necessity of repeat exposure for better diagnostic information such as patient motion or poor technical factors. **For computerized and automated systems the recording of technique factors is not necessary as long as the equipment is calibrated and maintained. OAR 333-106-045 requires the facility to determine the typical patient exposure for their most common radiographic examinations, i.e. technique chart.**

(f) Each film shall be properly identified by date of exposure, location of X-ray department, patient's name and number, patient's age, right or left marker and postural position marker; and **indication of the position of the patient**;

(g) The patient with tremors must be immobilized;

(h) The radiographs of a patient with an antalgic posture may be taken in an upright position only if the patient is adequately supported and immobilized to insure diagnostic quality. Otherwise, the recumbent position shall be used;

(i) Upright or postural views shall not be used for any patient whose size exceeds the capacity of the X-ray equipment. Penetration must be adequate on all films;

(j) ~~Full Spine (14 x 36 inch) radiographs~~: ~~**(A)**~~ Sectional views shall be taken in preference to a single 14 x 36 inch film if the patient’s size or height prevents diagnostic qualify on a single 14 x 36 inch film;

~~(B)~~ **(k)** If two exposures are made on a single film, the area of exposure shall be critically collimated to avoid double exposure of the overlapping area;

~~(C)~~ **(l)** All views shall employ graduated filtration or adequate devices to attenuate the primary beam for the purpose of reducing unnecessary radiation and to improve film quality. Split screens, gradient or graded screens, paper light barriers inside the cassette, or any other attenuating device in the beam between the patient and the film shall not be permitted, other than the grid controlling scattered radiation.

~~(k)~~ **(m)** A record of radiographic findings on every set of radiographs reviewed shall be included in the patient's permanent file;

~~(l)~~ **(n)** Radiographs shall be kept and available for review for a minimum of seven years or until a minor becomes 18 years of age, whichever is longer. (ORS 441.059, 684.025, 684.150)

STANDARDS

In addition to the legal requirements for taking x-rays in the State of Oregon, the following standards shall apply:

1. The chiropractic physician must make imaging decisions based on a demonstrated need (clinical necessity) and what is best for the patient.

2. Efforts should be made in all areas of the imaging procedure to provide the least possible dose to the patient without compromising image quality. [90]

3. Standard views for a minimum series of diagnostic radiographs are needed to evaluate each region of interest. As a general rule two views 90° to each other should be obtained. Some areas require additional views as an essential part of the minimal diagnostic series.

4. When radiographs are part of a biomechanical analysis it is paramount to evaluate images for pathologies that may weaken bony architecture, requiring modification of therapy

5. The choice of sectional or full spine views is dependant on clinical necessity and the ability to produce diagnostic quality radiographs.

6. Chiropractic Physicians are responsible for ordering necessary and appropriate imaging studies. Relevant pre-existing x-ray studies should be accessed, if possible.