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## CERVICAL SPINE RADIOLOGY FOR PHYSICAL THERAPISTS THE BASICS OF RADIOLOGY

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### INTRODUCTION

The study of radiology has long been considered beyond of the level of expertise of the orthopedic physical therapist by the medical community. Yet, physical therapists with their detailed knowledge of anatomy, biomechanics, kinesiology, and pathology are uniquely qualified to utilize radiographs in the clinical setting to improve quality of care. By utilizing radiographs and a detailed biomechanical assessment, a manually trained physical therapist may be able to differentiate radiographic changes that are typical of the aging process versus those that cause joint restriction and lead to significant pathological changes.

This article provides an introduction to basic radiographic principles and terminology. These basic principles will then be applied to evaluation of the normal and pathological conditions of the cervical spine. Hopefully, this article will stimulate interest of the reader to further expand his/her knowledge of radiology.

X-rays utilize electromagnetic radiation that is capable of penetrating the body's tissues. The amount of beam that is absorbed is dependent upon the density of the tissue. The plate is positioned to capture the particles of the beam that are not absorbed by the tissues of the body. Exposure to the x-ray particles causes the film to darken. Where the beam is absorbed the film is less exposed and therefore lighter in appearance. The denser the tissue, the more particles that are absorbed, the less the film is exposed, and therefore lighter in appearance. (7)

### MAJOR DENSITIES (7)

Air is the least dense material in the body and will therefore absorb the least amount of x-ray particles. This results in the darkest portion of the film. Bowel gasses are an example of air within tissue and are visible on lumbar spine radiographs. Fat is slightly more absorbent to x-ray particles than air, but both are still considered radiolucent or black on the film. Fat can be observed on radiographs of the calcaneus. Fat pads are also observed in the lateral view of the elbow joint that has sustained a radial head fracture. Swelling within the joint causes elevation of the fat pad away from the humerus and will show up in the film as an area of lucency anterior and posterior to the distal humerus.

Fluid is more absorbent than air or gas. Fluid is considered to be of intermediate radiolucency. Fluid can be evident in intraarticular injuries when the effusion is trapped by the surrounding joint capsule. For example, fluid can be observed on a plain film of an individual who sustained an anterior cruciate ligament tear.

Minerals, particularly calcium, are the densest, naturally occurring substances within the body. The amount of exposure is dependent on a number of factors. The bone itself can be of various densities, i.e. cortical bone is denser than cancellous bone. Various pathological processes will alter bone density, and therefore, change the amount of x-ray particles that are absorbed. For example, Paget's disease leads to a disturbance in bone metabolism that leads to a mosaic appearance of radiolucency and sclerosis, or areas of increased density.

### RADIOLOGY OF THE CERVICAL SPINE

#### STANDARD VIEWS OF THE CERVICAL SPINE (2)

Anterior to posterior view: the patient is either erect or supine. The x-ray beam is directed towards the C4 vertebra in an angle of 15°-20° in a cephalad direction. In this view the bodies of C3-C7 are well visualized, as are the uncovertebral joints and the intervertebral disc spaces. The spinous processes (remember they are bifid) are seen on end and appear to be teardrops on the x-ray. The view is evaluated primarily on alignment and symmetry of segments. The laryngeal and tracheal air shadows should be midline. Deviation may indi-

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## Notes from the Editor

As NAIOMT begins its ninth year since it was incorporated, it is helpful to reflect on where we have been and where we are headed as an organization. This past June, the faculty met to explore this question with the aid of facilitator Julie Huffaker. Several things became very obvious; we have grown and accomplished a great deal as a group and as individuals. In developing a strategy for the future, we recognize the need to build on or established relationships with professional and educational organizations (APTA, AAOMPT, Andrew's University, Pacific University, Texas Womens University), build new relationships, continue to work closely with the network of site coordinators and expand our resources for the Clinical Fellowship program. We intend to utilize and take advantage of new technology and the era of the internet as we revamp our exam process. The NAIOMT faculty look forward to serving the needs of the physical therapists in the US who work as becoming better manual therapists. We invite your participation in this process.

BILL TEMES, EDITOR

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cate space-occupying lesion or a retropharyngeal hemorrhage due to vertebral body fracture.

**The open-mouth view:** With the mouth open, the beam is directed perpendicular to the midpoint of the mouth. The open-mouth view allows evaluation of the odontoid process, the body of C2, the lateral masses of the atlas and the A-A joints. A normal x-ray should demonstrate symmetry of space in between the facets and the odontoid. The odontoid should be perpendicular to the anterior arch. There should not be any lateral overhang between the lateral masses of C1 and C2.

**Lateral view:** The lateral view can be taken with the patient sitting, standing, or in the case of trauma, in the supine position. In the standing the beam is directed to the center of C4 or at the level of the chin. This view is used to evaluate the vertebral bodies, spinous processes, and intervertebral disc space in the upper cervical spine. Close attention should be paid to the pre-dens space, also known as the anterior atlantodens interval (ADI). The ADI should not exceed 3 mm. A 3-5 mm ADI indicates rupture of the transverse ligament and greater than 5 mm distance indicates an accessory ligament rupture. (2)

**Oblique view:** The patient is rotated 45° to one side. To demonstrate the right-sided neuroforamen the patient is rotated to the left and the beam is directed to the right side of the C4 vertebra at a 15°-20° angle from the horizontal. The purpose of this x-ray is to assess the integrity of the neuroforamen.

### ABCS OF RADIOLOGY

When evaluating radiographs it is important to develop a systemic method that can be consistently utilized. One simple system that has been developed uses the mnemonic ABCS. (7)

**A: Alignment:** Establish bony alignment of the cervical spine by connecting lines drawn along the path of the anterior longitudinal ligament, the posterior longitudinal ligament, and the spinous process. The three lines should form three smooth parallel curves, demonstrating normal cervical lordosis. Loss of curvature may indicate muscle spasm or severe forward head posture. Malalignment may demonstrate fracture or ligamentous instability.

**B:** Evaluating **bony density** with knowledge that bone density changes may indicate serious systemic pathology. For

example, decreased density can be the result of rheumatoid arthritis, chronic steroid use, osteoporosis, and various metabolic diseases. (1,4,7)

**C: Cartilage spaces:** Evaluates the relative disc space with particular attention to C5-C6 and C6-C7 and T1-T2. Correlate lateral view to oblique view; to determine if the lack of disc space causes neuroforaminal encroachment.

**S: Soft tissue evaluation:** Soft tissue changes can provide important information in instances of trauma. For example, measurement of a space anterior to C2 to the posterior aspect of the pharynx should not exceed 5 mm on the lateral view. Distances larger than 5 mm may indicate underlying hemorrhage or soft tissue disruption. (2)

It is important that multiple views be utilized to rule out significant pathology. In one study of traumatic cervical spine injury approximately 60% had more than one fracture. It is also important to differentiate pathology from normal aging. Remember that there will be significant radiographic evidence of age-related changes. Up to 80% of asymptomatic patients over the age of 50 years old will demonstrate radiographic change of the cervical spine. (1) Therefore, base treatment on complete physical examination, not on radiographs alone.

## PATHOLOGY OF THE CERVICAL SPINE

### FRACTURES AND DISLOCATION

(1,3)

**Jefferson fracture:** This fracture typically results from a blow to the top of the head. The compressive forces are transmitted to the cranium and occipital condyles into the superior surfaces of the lateral masses outward. The resultant fracture is a symmetrical fracture of the anterior and posterior arches of C1 and disruption of the transverse ligament. The best view to see this injury is the open-mouth view.

**Odontoid fractures:** Fractures of the dens are typically a result of the hyperflexion of the upper cervical spine. With hyperflexion the dens is usually displaced anteriorly and may be associated with anterior subluxation on C2. One classification system that is utilized is based on the level of the stability of the resultant fracture. (2)

**Type 1:** Oblique fractures of the upper portion of the

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# Clinical Pearl: Thoraco-Lumbar Junction Mobilization

The Thoraco-Lumbar junction is an important transitional area. Anatomically it has characteristics that resemble both the vertebrosternal and chondral thoracic spine, as well as, the lumbar spine. The T11 and T12 caliper ribs present as atypical to the ribs superiorly with, in particular, the large trunkal muscle attachments at this junction. The T-L junction, like the other spinal junctions, has significant convergence of fascia which can make it a key area for dysfunction. Direct techniques of mobilization and manipulation specific to this area have been developed and proved valuable tools for treatment. However, it is my clinical finding that this area can be recidivistic in nature when long standing fascial restrictions are present and/or dysfunctional habitual gait or breathing patterns exist.

Prior to direct mobilization/manipulation of the T-L junction, closer examination of the diaphragm for tightness and lack of expansion may provide you with one clue to difficulty in getting mobility changes at the spine. A couple of effective preparatory techniques that I learned through Gregg Johnson, PT, FFCFMT of the Institute of Physical Arts, Functional Orthopedics™, will be described.

1. Patient in supine position with the therapist facing cranially. (The patient may need to be hooklying if they are particularly restricted myofascially in the region). The therapist places their thumbs approximately one inch inferior to the lower anterior border of the costochondral structures. This allows gathering of soft tissue as you curl gently under the costal arch. The patient will go through several breathing cycles. On each inspiration the therapist will allow radial deviation of their wrist to occur so they can maintain a hold of the end inspiratory position. When the patient attempts to exhale gently the therapists maintained position would cause the diaphragm to be mobilized. (The patient controls the stretch intensity by moderating their active breathing). The



therapist is a softening or increasing of elastic feel in the overpressure movement into inhalation. An additional movement of sidebending at the waist, can be done by pivoting through the weight bearing knees moving both ankles to the left then the right. Stay localized at the T-L junction. This utilizes the biomechanics of coupling to mobilize the joint simultaneously with the diaphragm stretch.

For chronic Thoraco-Lumbar junction dysfunction these preparatory techniques plus post mobilization/manipulation neuromuscular training of breathing and gait have proven very effective in getting efficient change to this region.

KENT KEYSER,  
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## Radiology continued from page 2

dens. This is an unstable fracture and is usually treated conservatively.

**Type 2:** Transverse fracture to the base of the odontoid. This is a stable fracture that is usually treated with fusion.

**Type 3:** Transverse fracture through the base of the dens and extends in the body of the atlas. Traumatic spondylolisthesis of C2 typically seen in hyperextension injury of the cervical spine. Commonly seen in the motor vehicle accident when the top of the head strikes the steering wheel or dashboard. May be as simple as a nondisplaced fracture through the pedicles of the axis or as fractures through the arches and anterior subluxation of C2 on C3.

**Burst fracture:** This is a compression fracture of the lower cervical spine. The mechanism of injury is similar to that of a Jefferson fracture. The nucleus pulposus is compressed into the vertebral bodies causing the vertebral body to explode outward, often in a posterior direction causing severe spinal cord injury.

**Tear drop fracture:** This is the most severe and unstable of cervical spine injuries. This fracture is characterized by posterior subluxation of the posterior elements, soft tissue disruption including the ligamentum flavum and spinal cord. The stress at the anterior longitudinal ligament causes it to tear or avulse from the anterior body in a small triangular or tear drop shaped fragment.

**Clay shoveler's fracture:** This is a vertical fracture of the spinous process of C6 or C7. This fracture is caused by a powerful flexion of the cervical spine. It derived its name as it is a common occurrence among clay miners in Australia in the 1930's. This is a stable fracture best visualized on the lateral view of the cervical spine.

## RADIOGRAPHIC FEATURES OF NONTRAUMATIC PATHOLOGIES OF THE CERVICAL SPINE ARTHRITIDES

**Rheumatoid arthritis:** Inflammatory rheumatoid arthritis (RA) is characterized by a diffuse narrowing of the joint spaces, periarticular osteoporosis, and systemic joint effusion. Chronic RA leads to the destruction of cartilage, ligaments, and tendons. The joints most affected by rheumatoid arthritis in the cervical spine are the atlanto-occipital joint, the atlantoaxial joint, and the atlantodens joint. In the most severe cases, subluxation of the A-A joint can occur anteriorly, posteriorly, or posterior-laterally. Subluxation of the A-A joint is defined as more than a 3 mm distance from the posterior edge of the anterior ring of C1 and the anterior surface of the dens. Anterior subluxation has been reported in 19-71% of patients with rheumatoid arthritis. (1)

Cephalad migration of C2, also known as vertical settling, is another concern with rheumatoid arthritis. Vertical settling occurs when the tip of the dens protrudes above the transverse diameter of the foramen magnum. Other common effects of rheumatoid arthritis are erosion in the popliteal joints and erosion of the spinous processes.

**Degenerative change:** Degenerative processes have important radiographic features that assist the clinician in dif-

ferentiating the age-related changes from other forms of arthritides. The degenerative process is evidenced as disc space narrowing, production of osteophytes, facet narrowing, and eburnation. Progression of degenerative changes can cause neural foraminal encroachment and single nerve root radiculopathy.

**Cervical spondylotic myelopathy** is another condition caused by progression of degenerative changes. Hypertrophy of the vertebral structure, central disc herniations, osteophyte formation, and ossification of the posterior longitudinal ligament may contribute to eventual compression of the spinal cord. The normal A-P diameter of the cervical spinal canal is 17-18 mm with the critical A-P diameter being 12-13 mm below which spinal cord compromise may occur. (1, 4, 6)

## INFECTIONS OF THE SPINE

Pyogenic infection such as vertebral osteomyelitis is more common in the lumbar and thoracic spine. Infectious organisms can reach the spine by several routes. The most common route is hematogenic. Another route of infection can also include direct contamination during surgical intervention. Radiographically infection of the spine demonstrates disc space narrowing and erosion of the vertebral end plate.

Spinal tuberculosis or Pott's disease most commonly occurs in the lower thoracic and lumbar spine and rarely affects the cervical spine. Radiographic features are similar to spinal osteomyelitis with disc space narrowing and destruction of adjacent vertebral end plate. TB may cause partial clots or complete disruption of the vertebral body.

Severe childhood infections of the pharynx, tonsils, or peritonsillar region may spread to the cervical spine region through the lymphatic system. These infections may cause severe instability of the upper cervical spine due to inflammation and disruption of cervical spine ligaments and joint capsules. This will be evidenced radiographically as an increase in the pre-dens space, which in normal children is typically 4-5 mm.

Ankylosing spondylitis is a chronic inflammatory disease of the joints of the axial skeleton that will normally begin in the SI joint and lumbar spine, but in more advanced cases the entire spine may be fused. Radiographically, ankylosing spondylitis is demonstrated by squaring of the vertebral bodies, thin syndesmophytes (paravertebral ossification that resembles an osteophyte except that it runs vertically, whereas an osteophyte has its orientation in a horizontal axis), preservation of disc space, fusion of apophyseal joints, ossification of prevertebral ligaments, and the resultant bamboo spine appearance.

## CONCLUSION

Given the proper training, physical therapists can use radiographs to improve the quality of care they are able to provide to their patients. I hope that this brief introduction to cervical radiology will stimulate further interest in the reader to seek more advanced training in the field of radiology.

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## Trunk Deviation and Site of Herniation

JIM MEADOWS, BSCTPT, MCPA, FCAMT

Many years ago Cyriax proposed that by observing whether the trunk list or deviation was towards or away from the painful side the therapist could predict the site of the disc herniation relative to the spinal nerve, that is whether it was positioned medially or laterally. If static deviation is towards the side of the pain then it is caused by a medial prolapse, if away from the painful side by a prolapse situated lateral to the nerve root. This model is predicated on the irritating effect of the herniation on the dural sheath or nerve tissue. However, other factors may determine the direction of any deviation in standing and these include leg length discrepancy, the biomechanical effect of the disc herniation, discogenic pain directly producing an antalgic posture as opposed to indirectly causing it via its pressure on sensitive structures etc. But we seem to have become fixated on the dural effect (Cyriax, McKenzie, De Palma). The question must be first "is there a disc herniation" not "how is the disc herniation situated". The presence of the so-called sciatic scoliosis by itself is not enough evidence to proclaim the existence of disc herniation. Once it has been decided that a disc herniation is causing the shift, are compression of dural and/or neural tissue enough to explain the direction of the deviation. The only study (as opposed to speculation) that I know of says no! Porter after a clinicosurgical study of 100 consecutive patients found that twice as many listed to the left than to the right but after excluding those with measurable leg length discrepancies, there was no correlation between the direction of the list and the site of the prolapse but possibly an association between hand dominance and side of list. The study did find, however, that the presence of a shift correlated moderately (.49) with the presence of a disc herniation of which twice as many existed at L5/S1 as at L4/5 which tends to blow another idea that the iliolumbar ligaments reduce the potential for listing and that those patients with lists are suffering from an L4/5 lesion. An association of trunk list with back pain was recorded in 100 patients, 5.6% of those attending a back pain clinic. Twice as many patients listed to the left as to the right. A total of 49 patients fulfilled the criterion of a symptomatic lumbar disc lesion, and 20 required surgical excision of the disc. The side of the list was not related to the side of the sciatica nor to the topographic position of the disc in relation to the nerve root. There is some evidence that the side of the list may be related to hand or leg dominance. (Porter). It can be seen that there are numerous reasons for a lateral shift and that about 50% of the time it MAY be due to a disc herniation. Conversely it is also apparent that in 50% of the cases the list MAY NOT be due to a disc herniation. First make sure that a disc herniation is causing the shift (to be addressed at a later date) and then worry about the site of the pressure.

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## Hoffmann's Reflex in

### Asymptomatic Patients

JIM MEADOWS, BSCPT, MCPA, FCAMT

You are considering a cervical treatment, traction, mobilization, manipulation whatever to a couple of cervical levels in a patient complaining of cervical pain. This patient denies any history of neurological symptoms that could be attributed to nerve root or cord compression. Being a conscientious therapist you have already carried out a complete scan including cord tests in the arms and legs. But because Hoffmann's test was either not taught on your previous courses or merely mentioned, you omit this test and concentrate on deep tendon reflexes, the extensor-plantar test and clonus testing all of which were negative. But, before you can treat this patient he/she volunteers the information that they have had an MRI which shows the presence of disc herniation and cord compression at the level you want to treat. Do you still go ahead with your treatment plans? And if you decide to do so how much information would you give the patient regarding the risk that treatment poses to the patient's well being? Do you even know?

One study (Boden) found that in 63 asymptomatic patients nearly 20% had MRI evidence of foraminal or cord compression. A recent study has demonstrated that there is small chance (a little less than 2%) that the patient under consideration will have an asymptomatic disc herniation with cord compression and that in over half of these patients, the compression is moderate to severe and is demonstrable on clinical testing (Sung). Now these are not studies demonstrating simple asymptomatic bulges on the disc, we are all used to those, but of significant compression of the spinal cord. Sung took 837 subjects and investigated Hoffman's test. This test was carried out in the standard way be flicking the nail bed of the third digit. It was considered positive if the terminal phalanx of the thumb, flexed regardless of any flexion of other digits or withdrawal of the arm. Those subjects who demonstrated a positive Hoffmann's response were questioned regarding the presence of paresthesia, gait abnormality, weakness, radiculopathy or bladder/bowel changes and excluded if they answered in the affirmative.

- 16 patients (2%) had a positive Hoffmann's reflex and no symptoms of neurological involvement.
- The average age of the 16 was 47 with a range of 24-74 years with males 3:1.
- 14/16 (87.5%) had spondylosis on radiograph
- 16/16 (100%) had pathology on MRI
- 15/16 (94%) had a herniated disc(s) with cord compression
- 1/16 (6%) had a T5-6 disc herniation that was considered unrelated

Of the 15 with cord compression:

- 6 were considered mild (anterior cord effacement with flattening)
- 7 were considered moderate (indented anterior cord)
- 2 were considered severe (indented and with an altered MRI signal from the cord)

There were 29 herniated discs among the 16:

- C2-3 = 2
- C3-4 = 3
- C4-5 = 13
- C5-6 = 11
- C7-T1 = 0

The 16 subjects were then examined neurologically with the following results:

- 7 (44%) had a "hyperactive" deep tendon reflex
- 3 (19%) had clonus
- 2 (12.5%) had a bilateral Babinski response to extensor-plantar testing

Those who had clonus also demonstrated "hyperactivity of the deep tendon reflex.

Those who had a Babinski response also demonstrated clonus and a "hyperactivity of the deep tendon reflex

The Hoffmann's test in this series was the only test that was positive in all subjects and do was clearly the most sensitive test.

While it is apparent that the Hoffmann's test will not detect all cases of cord compression (the Boden study testifies to that), it is also clear that the Hoffmann's test is perhaps our most sensitive clinical test for cord compression in the cervical spine.

Now to go back to my initial questions if you knew that a patient you were considering treating with mechanical means had a disc herniation compressing the cord at or near the level you were intending to treat, would you continue with your plans? You can now extend that question to if Hoffmann's test is positive would you continue with your treatment plans before getting more information given that a positive Hoffmann's is probably demonstrating exactly this.

I would suggest that Hoffmann's test be used routinely on all cervical pain patients as a screen for asymptomatic cord compression and if found to be positive, the therapist undertakes a serious re-evaluation of the treatment decision.

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