Spinal Imaging: An Update for the Treating Physical Therapist

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ABSTRACT

This monograph provides physical therapists with an update in evidence-based imaging practices, including paradigm shifts in radiography, magnetic resonance imaging, computed tomography, bone scintigraphy, dual energy x-ray absorptiometry, and ultrasonography. The responsibility of physical therapists to consider imaging in clinical practice to enhance the care of patients with cervical, thoracic, lumbar, and sacroiliac conditions is discussed. Appropriate consideration and use of imaging requires knowledge of strengths and limitations of various imaging modalities, familiarity with imaging guidelines, and recognition of clinical presentations that warrant immediate referral and/or imaging, which are covered in this monograph. Two case studies are provided to demonstrate appropriate use of imaging in physical therapy practice. The first case is a 53-year-old retail sales manager with idiopathic-onset, right lower extremity pain aggravated with standing and improved with sitting. The second case is a 42-year-old secretary who presents to physical therapy 10 days following a motor vehicle collision with worsening neck pain and headaches.

Key Words: back pain, diagnostic imaging, neck pain, spine

LEARNING OBJECTIVES

Upon completion of this monograph, the course participant will be able to:

1. Identify signs and symptoms of red flags and specific causes of spine pain that require emergent referral and/or immediate imaging.
2. Appropriately refer patients with acute and chronic spinal disorders for diagnostic imaging based on clinical practice guidelines.
3. Detail the advantages and disadvantages of various imaging modalities with respect to applications for spinal disorders.
4. Appraise whether or not imaging findings correlate to clinical presentations in patients with various spinal conditions.
5. Synthesize available patient examination findings with imaging evidence to develop more effective intervention strategies.

OVERVIEW

The American Physical Therapy Association's Vision Statement expresses that physical therapists (PTs) will direct and supervise their patient's care, including referrals as needed and will ensure services are of economic and prognostic value.[1] Spinal disorders are among the most common conditions treated by PTs.[2] To be recognized and respected as first-line practitioners for patients with spinal disorders, PTs will need to (1) identify signs and symptoms requiring emergent referral for the performance of imaging, (2) refer patients for the ideal imaging study at the appropriate time, and (3) interpret imaging findings with respect to the patient's clinical presentation. Physical therapists, acting in a primary care role, have a responsibility to ensure imaging is used discriminately to minimize unnecessary costs to patients and the health care system and when relevant, imaging findings are considered in determining ultimate recovery on a patient-by-patient basis. This course will provide PTs with the knowledge and skills to use spinal imaging to enhance their clinical practice.

Epidemiology and Health Care Utilization

Most individuals will experience spine pain in their lifetime, as the lifetime prevalence of neck and low back pain (LBP) may be as high as 86%.[3,4] One year prevalence rates for neck and LBP range from 0.8 to 82.5%[5-8]; mean prevalence is estimated at 25% for neck pain[3] and 38% for LBP.[7] Point prevalence for neck pain and LBP is 14.4%[3] and 18.1%,[7] respectively. Prevalence for thoracic pain is similar, as Briggs et al[9] reported thoracic pain lifetime prevalence as high as 77%.[9] In working men and women, one year and point prevalence for thoracic pain ranged from 3.0% to 55.0% (median: 30.0% for most occupations) and 3.0% to 44.0%, respectively.[9]

In the United States, the annual cost for treatment of neck and LBP increased by 65% from 1997 to 2005, which resulted in a total cost of $86 billion in 2005.[10] Following an initial episode of spine pain, approximately 60% of individuals fully recover by 3 months.[11] In those patients who return to work, 33% suffer recurrent episodes, resulting in missed work days.[12] Expenses associated with spine-related treatment and disability are disproportionately higher for individuals with chronic or recurrent spine pain as compared to those experiencing their first episode of pain.[13,14] Further, in contrast to patients without back pain, patients with back pain have higher average direct medical costs ($2,382 versus $7,211 [up to $33,931 with surgery]), respectively).[15] Among those with back pain, an order for imaging results in substantial costs for both patients and the health care system.[16] For example, with respect to magnetic resonance imaging (MRI), a 2012 study found 31% of lumbar spine scans were inappropriately ordered.[17]

Incidental Imaging Findings

Imaging should be used discriminately, to identify serious pathology and to guide interventions. Consider that 50% of patients report they would have surgery based on abnormal imaging findings, such as benign or incidental spinal abnormalities, even without corresponding symptoms.[18] Benign spinal abnormalities are common in children,[19] among individuals without pain,[20,21] and with aging.[22-24] Children frequently present with incidental findings of disc protrusions and Schmorl's nodes, ie, herniations of disc material through the endplate and into the vertebral body.[19] Among asymptomatic adults, 50% may have thoracic spine degenerative changes[25] and 37% may have thoracic disc protrusions.[26,27] In addition, vertebral body wedging at the thoracolumbar junction is common.[28] Incidental findings, including disc and joint degeneration, ligamentous hypertrophy, and annular fissures, increase with advanced age.[25,29] Other routine findings without established relationships to symptomatology include minor divergences from typical development, such as spina bifida occulta and transitional vertebrae.[30-33]

Given the prevalence of incidental spinal findings, clinicians should carefully review imaging abnormalities to determine whether or not structural abnormalities help to explain signs and symptoms. In 1998, Rankine and colleagues[34] reported that pain body diagrams were not good predictors of nerve compression per MRI. In 2000, Beattie et al[35] reported while mild-to-moderate nerve compression, disc degeneration or bulging, and central spinal stenosis per MRI were not associated with pain patterns, disc extrusion (ie, annulus fibrosis rupture with nucleus pulposus leakage) and ipsilateral severe nerve compression were associated with distal leg pain. Thus, currently available imaging applications may be most likely to correspond uniquely with a pain pattern of severe, unilateral LBP with concomitant radicular symptoms. When pain patterns do not correspond with imaging abnormalities, PTs have a duty to educate their patients. For example, if your patient's pain pattern is consistent with right L3 nerve root involvement and the MRI report indicates a mild right L5-S1 disc herniation, the MRI findings *may* be considered incidental. Patient education regarding discord between pain patterns and imaging findings may help patients to avoid interventional or surgical procedures that are unlikely to improve their clinical symptoms.

Practice Guidelines

At present, national practice guidelines discourage the use of routine spinal imaging and recommend imaging for investigations of severe or progressive neurological deficits, refractory pain, suspected serious underlying pathology, and for interventional and surgical planning.[24,36-39] Two well-recognized, evidence-based imaging guidelines are the American College of Radiology (ACR) Appropriateness Criteria and the Western Australia's Diagnostic Imaging Pathways. Adherence to these guidelines can assist providers in selecting the most appropriate imaging modality, enhancing patient care by reducing unnecessary examinations, and increasing the incidence of appropriate examinations for cost-effective diagnosis. Spine-relevant ACR Appropriateness Guidelines include the following: Chronic Neck Pain, Suspected Spine Trauma, Management of Vertebral Compression Fractures, Osteoporosis and Bone Mineral Density, and Stress Fracture, including Sacrum, Excluding Other Vertebra. Western Australia's Diagnostic Imaging Pathways relevant to spinal imaging include Neck Pain (Nontraumatic), Cervical Spine Injury, Thoracolumbar Spine Trauma, and Low Back Pain.

Utilization of imaging guidelines may help to curb indiscriminant and substantially expensive imaging,[40-42] and in some cases, recommends the use of imaging modalities with no ionizing radiation, reducing exposure of patients to unnecessary ionizing radiation.[43-45] Multiple studies have also demonstrated that when imaging is used, outcomes are not necessarily superior, and in fact, early imaging may result in worse patient outcomes.[40-42,46,47] In a meta-analysis, which included results of 1804 patients, outcomes of patients with LBP who received usual clinical care with or without immediate imaging were compared.[36] With respect to short- and long-term outcomes, no significant group differences were found for pain or function.[36] Further, imaging findings, such as disc degeneration, disc bulges, annular fibrosis tears, and vertebral Modic changes, appear to have no bearing on the therapeutic outcome.[48]

SPINAL IMAGING MODALITY OPTIONS

Radiography

While advanced imaging may often be used because of greater diagnostic capacity for many conditions, radiography still has an important role in spinal imaging. Radiography is widely available, cheaper than more advanced imaging techniques, and excellent at imaging bone and joint spaces.[49] Radiation exposure and limitations of single plane imaging are considerations with radiography. Routine radiographic series of the cervical spine contain at least 2 views, oriented 90° from one another, such as anterior-posterior (A-P) and lateral views. The A-P view allows visualization of the C3-7 vertebrae, while the upper cervical vertebrae are better viewed with an A-P odontoid ("open-mouth") view, due to the superimposition of the mandible over C1-2. Clinicians may check the A-P view to see if spinous processes are in midline with the pedicles and equal distance from the midline; inequalities may indicate a facet dislocation.[50,51] Odontoid views may be informative; the dens should be in midline, the borders of the C1 lateral masses should be contained within the borders of the C2 vertebra, and the joint spaces between C1 and C2 should be equal bilaterally. Radiographic abnormalities may indicate a fracture or dislocation.[50,51] An adequate lateral view allows visualization of C1 through the C7-T1 interspace.[51] Clinicians should look for 3 parallel curvilinear lines that lie along the anterior vertebral bodies, the posterior vertebral bodies, and at the spinous process and lamina junction (ie, the spinolaminar line). The vertebral bodies, disc spaces, and facet joints are easily discerned on a lateral view. When determining the cervical level, convention dictates counting from the upper cervical to the lower cervical spine.[52]

Right and left oblique views, used to visualize the intervertebral foramen and assess for fracture of the pars interarticularis (as occurs with spondylolysis), and functional radiography (eg, flexion-extension films) are *not* routinely recommended.[53] Functional radiographs, taken at the end ranges of active cervical range of motion, may be ordered when there is no fracture present but ligamentous injury is suspected (perhaps due to slight malalignment, including disruption of the parallel lines, on the lateral radiograph) in cases of subacute and chronic neck pain.[54] Acutely following cervical spine trauma, however, dynamic radiography in most circumstances is inferior to computed tomography (CT) and MRI.[55] Flexion-extension films may be used to evaluate anterior cervical fusions postoperatively to assess for fusion failure (eg, pseudoarthrosis), which appears as a distance of 1 mm or more between adjacent spinous processes.[56] For posterior cervical fusions, CT may be the preferred imaging modality for detecting fusion failure due to removal of spinous processes during the laminectomy.[56] In summary, given that up to 20% of cervical spine fractures may be missed with radiography,[57-59] MRI or CT, in the cases of suspected ligamentous injury or fracture, respectively, are more appropriate than radiography.[51] Dynamic radiography may have some value in the assessment of subacute and chronic neck pain, including assessment of anterior fusion integrity.

Routine radiographic series for the thoracic spine include an A-P and a lateral view. Additional views may include a swimmer's lateral view or bilateral oblique views, which allow visualization of the cervicothoracic junction and/or a coned view of the thoracolumbar junction.[60-62] The A-P view provides information on vertebral body and disc space height and allows assessment of interspinous and inter-pedicle distance. Disruption of the typical butterfly-shaped shadow overlying the vertebral bodies may indicate a fracture-dislocation or subluxation. Similar to the cervical spine, 3 parallel lines, shape and size of the vertebral bodies, and disc space preservation can be visualized on a thoracic spine lateral view. The right and left pedicles are superimposed, while the intervertebral foramina are easily visualized. Determination of the vertebral level may occur by counting inferiorly from the first rib-containing vertebra or superiorly from the most inferior rib-containing vertebra.[52]

When evaluation of the cervicothoracic junction is necessary, bilateral oblique views may be preferred over swimmer's views.[60] Similarly, a coned (or collimated) view of the thoracolumbar junction may assist with improved visualization of the thoracolumbar transition.[63,64] In both cases, advanced imaging may be warranted if a fracture is suspected immediately following a traumatic event. For detection of thoracic fractures, both of traumatic and atraumatic mechanisms, radiography may be specific (54% to 100%), but not necessarily sensitive (41% to 73%).[61,65] Consequently, radiography as a screening tool for suspected thoracic fractures is cautioned, particularly in cases of trauma, where omission of plain radiography in lieu of CT may expedite the evaluation process.[65,66]

In presentations of atraumatic, acute nonspecific LBP, with or without radicular pain, *routine imaging* is not recommended, unless suggestions of serious underlying pathology exist (see section on Red Flags).[67] Routine radiographic series for the lumbosacral spine include A-P and lateral views.[62] As with A-P views in the cervical spine, the clinician can check that spinous processes are in midline, interspinous intervals are similar, pedicles are an equal distance from the midline (located adjacent to spinous processes), and articular processes overlapping the vertebra result in the classic butterfly-shaped shadow (Figure 1A). Assessment of the 3 parallel lines (anterior spinal line, posterior spinal line, and spinolaminar line), vertebral body shape and size, intervertebral disc spaces, pedicles, and intervertebral foramen can be made on lateral views (Figure 1B). Vertebral level determination is made by counting superiorly from the first non-sacral vertebra or inferiorly from the first non-rib-containing vertebra.[52] The counting approach should be documented as there can be sacralization of the last lumbar vertebra or lumbarization of the first sacral vertebra[32] resulting in inter-examiner level identification differences, especially since segmentation variations are often unreported.[68]

Additional views may include right and left oblique views, a coned (or collimated) lateral view or angled A-P view of the lumbosacral junction, and/or functional imaging, ie, flexion-extension, traction-compression, and side-bending radiographs.[62] Specifically, inclusion of oblique and/or coned lateral views, exposes the patient to at least a two-fold increase in radiation dose and rarely result in a change in diagnosis.[69] The lumbosacral junction, a transitional region between the freely mobile lumbar spine and less mobile sacrum, is subjected to high shear forces,[70] and thus, is prone to injuries, such as spondylolysis and spondylolisthesis, and degenerative spondylosis. Although oblique view radiography has historically been used for investigation of pars interarticularis lesions, recent evidence suggests oblique views offer relatively low diagnostic yield. These views are not included in current imaging guidelines.[71-73]

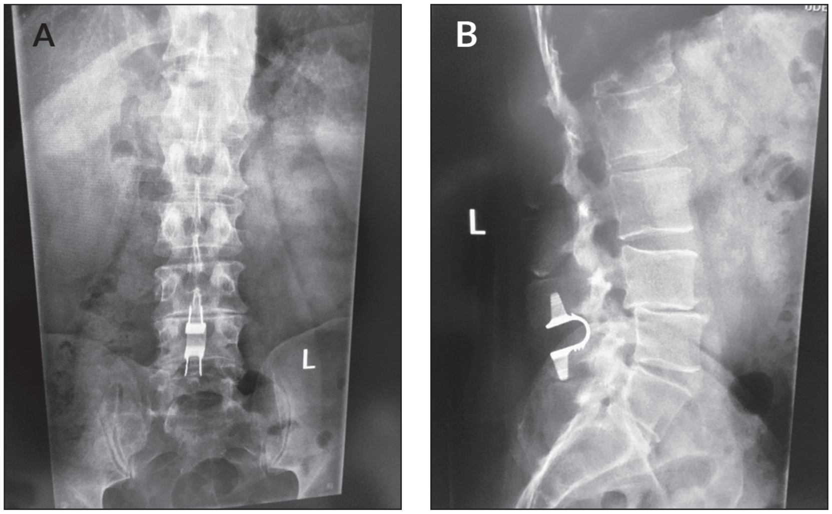

Figure 1. Lumbar radiographs of a patient postoperatively with a CoFlex implant.

Anterior-posterior (A) and lateral (B) radiographs in a patient following a CoFlex® interlaminar stabilization procedure. This titanium metal implant is used to stabilize the spine after surgical decompression for spinal stenosis, in lieu of fusion techniques that use metal rods and screws.

Dynamic radiography has been historically used to diagnose lumbar or lumbosacral instability.[74] Current practice standards and imaging guidelines, have replaced dynamic radiography with CT and MRI. Dynamic radiography is now considered to be a complimentary imaging series, in part, due to findings of 'radiographic instability' in individuals without LBP.[75] When flexion-extension films are obtained, translations of ≥ 4.5 mm or > 15% of the vertebral body A-P diameter or rotation of > 15° at L1-2, L2-3, or L3-4 or 20° at L4-5 or > 25° at L5-S1 may be indicative of radiographic instability.[76] Sagittal rotation, however, can be as high as 25° in healthy, non-symptomatic individuals, exemplifying the issue with such cut-points.[75] Traction-compression radiographs have questionable value in the diagnosis of lumbar instability and side-bending radiographs may be obtained when lateral flexion instability is suspected and flexion-extension films are negative.[74]

While a portion of the sacrum is included in a lumbosacral series and the posterior sacrum is visible on an A-P view of the pelvis, additional imaging may include a cephalad-angled A-P view of the sacrum and a lateral view of the sacrum and coccyx.[62] Bilateral oblique views may be used to evaluate the sacroiliac joints when indicated.[62] Radiography, however, as the sole imaging modality for sacral pathology is generally insufficient. This is due to the natural sacral inclination and overlying structures, including the bowel and bladder,[77] and as certain sacral pathologies are often radiographically occult, such as sacral insufficiency fractures.[78,79]

Primary kyphotic curves, ie, thoracic and sacral, and secondary lordotic curves, ie, cervical and lumbar, are viewed on lateral images. In adult spines with minimal degenerative changes, normal curvatures for the cervical, thoracic, and lumbar spines have been reported to be 20°, 35°, and 29°, respectively.[80] Malpositioning of vertebral bodies, as noted on lateral views when there is disruption of the parallel lines, can be indicative of spondylolisthesis or slippage subsequent to spondylolysis of the superior vertebra on the inferior vertebra.[52] Malposition may be termed anterolisthesis for anterior displacement of the superior vertebra or retrolisthesis for posterior displacement of the superior vertebra.[52] Abnormal lateral deviations of the vertebral bodies, including scoliosis, are viewed on A-P images; scoliosis is defined as > 10° of deviation from the midline.[52] Diminished vertebral body height, which may be indicative of fracture, osteoporosis, or other bone-compromising, pathological processes, is apparent on A-P views. In healthy spines, vertebral body heights increase from the cervical to the lumbar spine, averaging 1.4 cm in the cervical spine, 1.8 to 2.3 cm in the thoracic spine, and 2.8 cm in the lumbar spine.[80,81] Decreased vertebral body height may be indicative of kyphosis or fracture. Scoliosis and kyphosis that is painful or progressive may warrant additional radiographic views and/or advanced imaging.[16] Additional radiographic views and/or advanced imaging, such as MRI or CT, may also be appropriate if the patient (1) is < 20 years or > 50 years with symptoms and signs of systematic disease, (2) has abnormal laboratory results, (3) has a significant activity restriction exceeding 4 weeks, (4) is nonresponsive to at least 4 weeks of treatment, and/or (5) has worsening of signs and/or symptoms.[16]

Magnetic Resonance Imaging

Magnetic resonance imaging allows for multi-planar, noninvasive, spinal imaging without exposing the patient to ionizing radiation,[49] although the mean expense of performing a magnetic resonance examination in the United States is over 10 times that of a two-view radiographic series ($1301 versus $113, respectively).[82] Magnetic resonance imaging is considered the gold standard for evaluation of soft tissues (ie, muscles, ligaments, and discs), neural structures, and the interfaces of musculoskeletal anatomy with neural structures.[83] For example, MRI can be used to determine if nerve root compression is responsible for a patient's clinical presentation as in the case of radicular symptoms and signs. In the spine, typically a posterior disc herniation of a given motion segment, eg, C5-6, L4-L5, affects the inferior nerve root,[84] ie, C6 and L5 respectively, in this example. Far lateral disc herniations of the lumbar spine are an exception to this rule and affect the nerve root of the upper segment.[84] Magnetic resonance imaging is also the preferred imaging modality for evaluating spinal neoplasms, spinal cord