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Diagnostic Ultrasound: PLL and ALL Fibrosis

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The spinal tissues capable of transmitting pain (nociception) include the posterior longitudinal ligament (PLL), anterior longitudinal ligament (ALL), muscles, fasciae, facet joints, nerve root dura, and outer layer of the disc.^{1,2} Diagnostic ultrasound (DUS) is a widely-used diagnostic imaging procedure which employs the use of sound waves transmitted into the body and records the rate that the echoes are returned back to a receiver. Musculoskeletal ultrasound is best used to evaluate muscles, tendons, ligaments and bursae.³

During the routine evaluation of a spinal musculoligamentous injury, DUS can be used to identify inflammatory changes to several of the tissues (PLL, ALL, muscles, fasciae and facet joints) known to transmit pain. The use of DUS for the definitive diagnosis of disc herniation, spinal stenosis, and nerve root pathology is inadequately studied and its' routine application for these purposes only cannot be supported by the evidence at this time.⁴

PLL and ALL Inflammation

Hyperflexion/hyperextension (CAD) injuries commonly result in a partial distractive tearing of the PLL and/or ALL. The PLL runs along the posterior surface of the vertebral bodies, narrowing over the middle of the bone and expanding over the ends of the bodies and discs where it is anchored firmly and, like its anterior counterpart (ALL), it acts as a powerful stabilizer of the intervertebral joint.⁵ (For future discussion in the article, the "central portion of the PLL" will refer to the main body of the ligament and the "lateral extensions of the PLL" will refer to the expansion of the PLL over the vertebral bodies and discs.)

Plain films, MRI and CT scans are not considered good or cost-efficient imaging modalities for diagnosing partial tears (sprain) or tension (bulge) to the PLL or ALL. DUS offers a noninvasive, objective means to evaluate acute fibrotic changes to the PLL and ALL. The utilization of intervertebral joint and longitudinal scanning allows the PLL and ALL tissues to be within the view of the sonogram, since it is not obscured by bony or other hard tissues.

Spinal DUS Imaging

DUS is noted as a diagnostic imaging modality that has increased sensitivity to pathological changes in regard to soft tissues. The identification of various osseous spinal landmarks has been identified with DUS,^{6,7,8,9} which is a necessary reference in identifying normal and abnormal conditions.

Normal sonographic appearances of muscular, ligamentous and tendinous tissues have been determined and correlation of sonographic and histologic findings in abnormal or pathologic states have been monitored over specific periods of time.^{6,10} The sonographic appearance of tissue is definitely dependent on its current physiologic state. An acute or recent onset of an immuno-histologic response will alter the sound velocity as it travels through a visco-elastic medium differently than it would for a long-standing or fully resolved medium.^{6,11}

DUS of the spine is performed by placing a 5.0 MHz linear array transducer over the vertebrae in the transverse plane, aligned perpendicular to the segment being examined. The anechoic (black) shadowing of the spinous process, lamina, transverse process and vertebral body should be noted.

Soft tissue inflammation (fibrosis) appears hyperechoic (white) relative to the surrounding tissues. Acute injuries appear more echoic than resolving or chronic injuries. The degree of inflammation is directly related to the severity of the lesion and resultant scarring.

Sonographically, the PLL is located approximately 4-6 mm deep, anterior to the spinolaminar junction. The ALL is located approximately 7-8 mm deep. The actual location of these structures are dependent on the patient's age and body size.

Although most of our understanding concerning the healing characteristics of ligaments comes from our peripheral joints, it can be assumed that spinal ligaments behave much the same. Healing of ligaments occurs with fibrous repair (scar tissue) rather than by regeneration of damaged tissue.¹² DUS can identify inflammatory changes to soft tissues within 48-72 hours after a trauma.

Healing of ligaments occurs in three phases. Phase 1, the acute inflammatory phase, lasts up to 72 hours. It is characterized by a humeral response and a cellular response. Phase 2, the repair phase, lasts from 48 hours to six weeks and is characterized by synthesis and deposition of collagen. Collagen will contract between 3 and 14 weeks post-injury, but may take up to 6 months. Phase 3, the remodeling phase, lasts from 3 weeks to 12 months or more. During this phase, collagen is remodeled to increase its' functional capacity.¹² The

degree of fibrosis is directly related to the amount of residual scarring.

Healed ligaments contain immature type III collagen, which is deficient in cross links, and the quantity of fibers is less than in normal ligament, which is composed chiefly of type I collagen.¹²

Stipkovich has categorized the fibrotic changes to the PLL into four separate types:¹³

Type 1: involves only the lateral extensions of the PLL.

Type 2: involves only the central PLL.

Type 3: involves the central PLL and one side of lateral extension.

Type 4: involves the central PLL and both lateral extensions.

Foraminal encroachment cannot be directly visualized with DUS. However, it is known that acute inflammatory reactions within the capsules of the apophyseal and interbody joints and of the superficial layer of the PLL overlying the lateral interbody joints give rise to swelling and, therefore, foraminal encroachment. DUS can identify inflammatory changes in these areas.

Follow-up studies are also an important consideration. If the inflammation persists without the proper diagnosis and treatment, it becomes a chronic condition, and hyperplasia of the capsular and ligamentous structures occurs to cause continued narrowing of the intervertebral canals.¹⁴

The use of DUS to diagnose nerve root pathology appears to be inadequately studied at this time. The use of the term "nerve root area" inflammation has created some controversy due to the close anatomical proximity of the exiting spinal nerve roots and lateral extensions of the PLL (Type 1). In this author's opinion, the term "nerve root area" inflammation appears to describe an anatomical location which allows for the diagnostic possibility of ligamentous fibrosis and/or perineural fibrosis. In either case, inflammatory findings in this area are always considered abnormal and clinical correlation is indicated.

The use of DUS to definitively diagnose intervertebral disc herniation also appears to be inadequately studied at this time. However, it is known that the PLL not only deforms due to the relative separation between two adjacent vertebrae, but also due to bulging of the disc.¹⁵ During the routine spinal DUS evaluation, the clinician may also observe the suggestive signs of disc herniation. The sonographic presence of a posterior curve associated with the central PLL (Types 2-4) inflammation may be considered suggestive, although not diagnostic, of tension to the PLL as a result of a recent disc bulge. The presence of this finding indicates the need for clinical correlation and the consideration of additional diagnostic testing.

The absence of this finding may lessen immediate need for MRI/CT imaging for the diagnosis of an acute disc bulge unless otherwise clinically indicated.

Conclusion

Acute distractive injuries to the PLL and ALL are common following hyperflexion-hyperextension type injuries. The PLL, ALL and the intervertebral disc act as powerful stabilizers of the spine. The PLL and ALL are known to transmit pain, and its diagnosis cannot be underemphasized following spinal trauma.

The role of DUS for the definitive diagnosis of disc herniation is still inadequately studied at this time, however, changes to the central PLL can be considered a suggestive sign for disc herniation. In the near future, DUS may be considered as a noninvasive, inexpensive screening modality for disc injury prior to MRI.

DUS is a joint-specific means to determine the vertebral levels involved, acuteness of the injury, severity of the injury, and progression of the injury through the course of treatment. Once the injury has been properly identified, the appropriate treatment plan can be applied.

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