Seminars in
SPINE
SURGERY

Current Status of Imaging of the Intervertebral Disc

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A brief review of intervertebral disc anatomy and the pathologic changes seen with degenerative disc disease is presented. Degenerative changes may be seen in all three components of the intervertebral disc: the annulus fibrosus, the nucleus pulposus, and the vertebral endplates. Findings seen in disc degeneration by plain radiographs, computed tomography, myelography, magnetic resonance imaging, and discography are summarized. Current and proposed methods for classification of degenerative disc changes are discussed. Finally, mention is made of emerging techniques and future methodologies for improving understanding between the imaging findings of degenerative disc disease and the development of pain.
Semin Spine Surg 19:58-64

KEYWORDS degenerative disc disease, spine, magnetic resonance imaging, computed tomography, discography

To appreciate the information provided by current methods of imaging the intervertebral disc, the anatomy of the intervertebral disc and the pathological changes that it undergoes must be understood. As such, this article begins with a brief review of these topics.

Imaging of the intervertebral disc typically begins with plain radiographs. Magnetic resonance imaging (MRI) is often the next imaging study obtained and changes associated with degenerative disc disease (DDD) can be seen in the nucleus pulposus, annulus fibrosus, and vertebral endplates. Computed tomography (CT), myelography, and discography may also be used to evaluate for DDD. However, while MRI and other advanced imaging studies provide excellent anatomic detail and may correlate back pain to pathologic findings, they do not provide a definitive diagnosis in all patients with back or neck pain.

Thus, new imaging methods, including dynamic imaging and T2 relaxometry, are being investigated to better define the relationship between anatomical and pathological findings with symptoms in DDD. Classification schemes are also being devised and refined to better allow researchers to categorize imaging results and correlate them with surgical results, genetic findings, and other outcome measures.

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Anatomy of the Intervertebral Disc

The intervertebral disc comprises three main components: the nucleus pulposus, the annulus fibrosus, and the vertebral endplates (Fig. 1). The vertebral endplate is a concave bony plate with an elevated rim created by the attached ring apophysis. This attachment produces a central depression in the endplate that is filled with hyaline cartilage (Fig. 2). The disc proper attaches to the superior and inferior vertebral bodies via the vertebral endplates centrally, and through ligamentous attachments to the annulus fibrosus peripherally. The two facet, or zygapophyseal, joints posteriorly make up the remainder of the spinal motion segment (Fig. 1). Each motion segment allows for movement in the sagittal, coronal, and axial planes.[1]

The annulus fibrosus has a tough outer layer comprising type I collagen fibers in concentric alignment forming lamellae that are thickest anteriorly (Fig. 2). These fibers are attached to adjacent hyaline cartilage and to the ring apophysis periosteum via Sharpey fibers. Annular fibers merge with the anterior and posterior longitudinal ligaments. The inner annulus is made up of fibrocartilage with a high percentage of type II cartilage.[2]

The nucleus pulposus is a remnant of the embryonic notochord and is made up of type II collagen and a proteoglycan matrix. The matrix proteins are negatively charged leading to the absorption of water, which increases resistance to compressive forces.[2]

In healthy adults, the intervertebral disc is largely avascular. Nutrition is supplied by diffusion through the endplate to

 1040-7383/07/$-see front matter
doi:10.1053/j.semss.2007.04.001

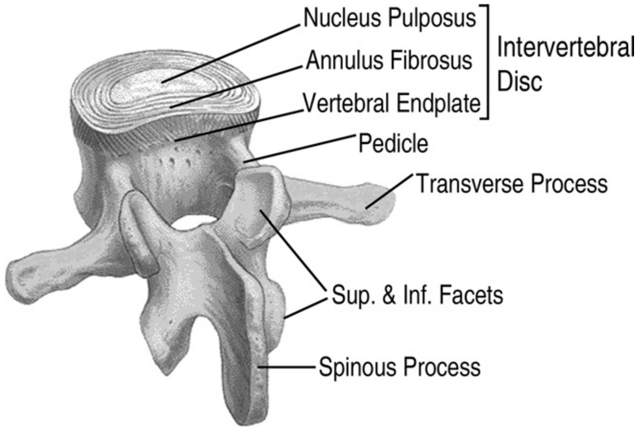

Figure 1 Lumbar vertebrae. The intervertebral disc comprises the annulus fibrosus, nucleus pulposus, and superior and inferior vertebral endplates. Only the inferior vertebral endplate is shown. The spinal motion segment comprises three components: the intervertebral disc and the two facet joints.

the nucleus pulposus and annulus fibrosus. The annulus has blood vessels only in its most superficial lamellae, while the nucleus itself has no blood supply. Chondrocytes and fibroblasts are responsible for the anabolic functions of the disc with catabolic functions provided by matrix metalloproteinases. The balance between catabolism and anabolism in the intervertebral disc is pH dependent, with a normal pH between 6.9 and 7.1. Inflammatory changes, changes in pH, and nutritional deficiencies can alter this balance.[1]

Weight-bearing is uniformly distributed across the disc plane. The gelatinous contents of the nucleus acts as a non-compressible mass which bulges outward against the intact fibers of the annulus, resulting in an even distribution of force over the entire area of the disc. The majority of the load is born by the nucleus.[1]

Intervertebral Disc Pathology

Age-related changes as well as acute events can lead to a breakdown in the disc and an alteration in the normal mechanics of loading. There are two sources of injury to the disc that can result in injury: first, a break in the continuity of the vertebral endplate, also known as microfracture; and second, an annular tear from torsional overload. These changes shift the distribution of weight-bearing more toward the annulus. Repetitive stresses lead to the development of more tears in the annulus and ultimately to loss of annular integrity. Herniation of the nucleus and diminished disc height may result (Fig. 3).[1]

Chemical changes are also seen with injury to the intervertebral disc complex. Microfracture of the vertebral endplate allows the introduction of inflammatory cytokines into the disc space with resultant decrease in pH, reduced oxygen diffusion, and a rise in lactate. This accelerates disc degeneration by slowing the anabolic processes and augmenting metalloproteinase activity.[1]

Current Imaging Techniques

Radiographs

In the patient with suspected DDD, plain radiographs are the initial diagnostic test of choice. Disc space narrowing, development of endplate sclerosis and osteophytes, and occasionally gas formation in the disc may be seen (Fig. 4). Typically, involvement of a single disc is seen. Although obtaining flexion-extension radiographs may show retrolisthesis, angulation, or increased translation, most patients with advanced disc degeneration show a decrease in motion across those segments.[3]

Computed Tomography—Myelography

CT scans may reveal marginal osteophytes and foraminal stenosis. Disc space vacuum signs arising from intradiscal collections of nitrogen and endplate sclerosis can also be better visualized by CT rather than plain radiographs (Fig. 5). Although the addition of myelography can show root-sleeve blunting in the foramen secondary to foraminal stenosis,[3] myelography is now rarely used in the diagnostic workup.

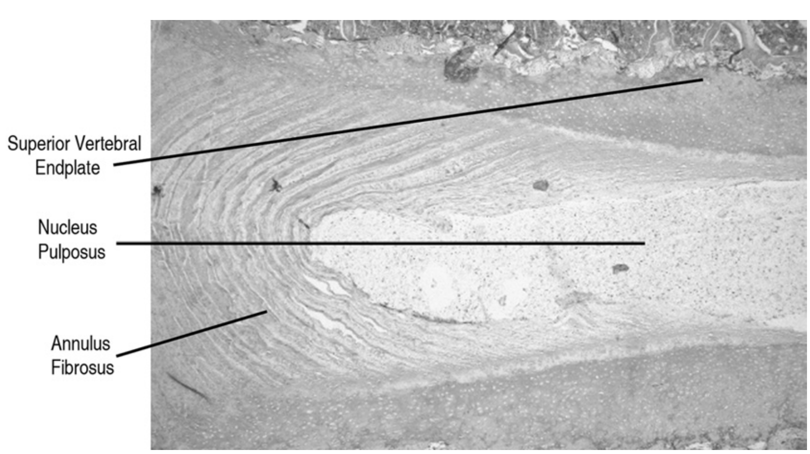

Figure 2 Components of the intervertebral disc. Note the hyaline cartilage which fills in the central depression due to the ring apophysis.