Loeser, John D.
Bonica's Management of Pain, 3rd Edition

CHAPTER 75

INTERVERTEBRAL DISK

Part of "CHAPTER 75 - General Considerations of Pain in the Low Back, Hips, and Lower Extremities"

The vertebral bodies of the lumbar spine articulate with one another through amphiarthrodial joints, which are termed *intervertebral disks* (Fig. 75-10). They are therefore by definition nonsynovial. In the transverse plane the cross section of the intervertebral disk is kidney shaped, corresponding to the shape of the vertebral body above and below. In the sagittal plane the disk is slightly thicker anteriorly than posteriorly, which may in part contribute to the lordotic posture of the lumbar spine (2).

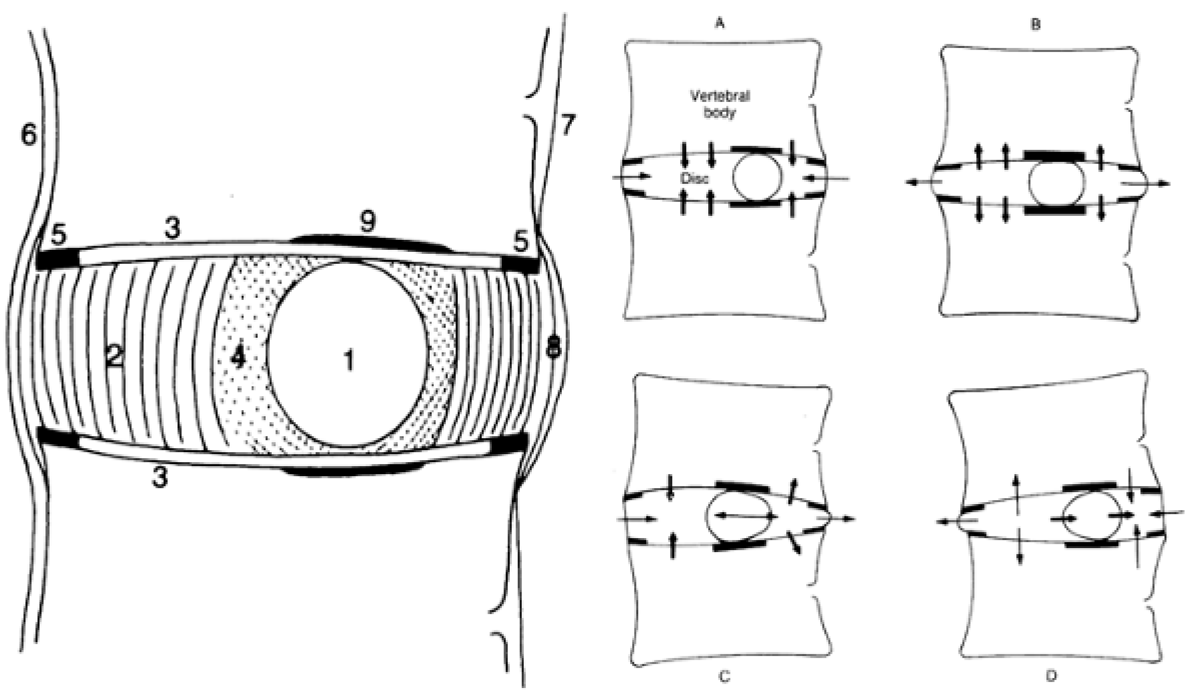

Figure 75-10. A: This diagrammatic representation of the intervertebral disk, in addition to presenting the customary nucleus pulposus (1), annulus fibrosus (2), and cartilaginous end-plates (3), also presents the zone of irregular connective tissues surrounding the nucleus (4), the epiphyseal rim (5), the anterior longitudinal ligament being continuous with the periosteum (6), and the posterior longitudinal ligament separating from the concave posterior vertebral body (7), the presence of Sharpey's fibers (8), and a thickened calcified layer capping the nucleus (9). **B:** The nutrient cycle to the disk is schematically depicted. (*A*) The weight is off the disk, permitting the polysaccharide molecules to imbibe fluids essential for nutrition. (*B*) The weight-bearing phase is represented, and the fluid is shown as being expressed from the disk. (*C*) Illustrated is backward bending, which may take place even at rest on an overly firm mattress. Here, while the front of the disk absorbs

nutrient fluids, the back of the disk is unable to do so. (*D*) Forward bending, the reverse of Figure C, is illustrated. An additional feature of forward bending is that with sufficient fluid moving posteriorly, hydrodynamics of the disk are upset and the patient may become fixed in flexion. (Reprinted from Paris SV. Anatomy as related to function and pain. *Orthop Clin North Am* 1983;14:476–477, with permission.)

The intervertebral disk consists of two major portions: a central gelatinous portion, the nucleus pulposus, and a circumferential portion, the annulus fibrosus.

Nucleus Pulposus

The nucleus pulposus is enclosed by the surrounding annulus fibrosus at the periphery and by a cartilaginous end-plate on the adjacent vertebral bodies. It consists of water and connective tissue elements including collagen and proteoglycans, as well as cellular components. The proteoglycans and collagen are constantly being degraded and replaced by the cellular structures within the nucleus. Water is the most predominant substance in the disk, accounting for 90% of the total volume (3). Proteoglycans contribute 50% of the dry weight, while collagen contributes only 15% to 20% (4). Although the mechanical properties of the disk are dependent on all of these components, the water content is probably the most important, and it is largely determined by the hydrophilic nature of the proteoglycans. It does, however, also vary with the type and extent of mechanical loading, age, as well as other factors that contribute to the overall nutritional status of the disk.

Annulus Fibrosus

The annulus fibrosus is a structure that is largely made up of collagen. The collagen fibers are attached to the peripheral margin of the adjacent vertebral bodies. The structure of the annulus has been likened to that of an onion. It consists of a series of approximately 20 concentric layers or lamellae. The collagen fibers in each layer are in a parallel arrangement oriented obliquely at about a 50-degree angle relative to the surface of the vertebrae (5). In each consecutive layer the fibers are oriented in an opposite direction to those in the previous layer. In the adult spine the nucleus resides in a somewhat posterior position in the intradiskal space, and the lamellae are therefore thinned in this region. The outer margin of the annulus does

P.1480

have a limited vascular supply and neural supply. The innervation of the outer portion probably includes both nociceptive and mechanosensitive nerve fibers.

In the human the intervertebral disk is the largest avascular structure in the body. Nutrients enter the disk and waste products leave the disk largely by diffusion to and from vascular structures in adjacent tissues. The cartilaginous end-plate that separates the nucleus from the vertebral body above and below is the most important source for nutrients, with the peripheral margin of the annulus providing a secondary source. Smoking, increased age, and vibration result in an accumulation of metabolites and a reduction in oxygen use (4). Mechanical loading seems to enhance disk nutrition as well, as evidenced by studies of the effects of spinal fusion on disk metabolism (6,7).

Anatomic Changes in the Disk during Development

There is considerable controversy about whether the gross, histologic, and biochemical changes that occur in the lumbar spine with increasing age are pathologic or simply a consequence of normal aging. The anatomic changes that are typically seen with increasing age are an increase in collagen content and deposition of lipofuscin and amyloid in the nucleus. In addition, small concentric clefts form in the posterior portion of the annulus that may coalesce to form larger and more radially oriented clefts. The cartilaginous end-plate may show changes of thickening or defects and fissuring with associated Schmorl's nodes. These changes are associated with the development of marginal osteophytes at the edges of the vertebral body adjacent to the disk. Although classically the degenerated disk has a reduction in water content and a reduction in height, the disk height may be increased with age when there is concomitant osteoporosis. Osteoporosis leads to collapse of the vertebral end-plates and an increase in vertical dimension of the disk, especially the central portion (8).

Function of the Intervertebral Disk

The function of the intervertebral disk at its most rudimentary level is to simply allow multiplanar motion between the rigid structural elements of the vertebral bodies. The nucleus behaves as a viscous fluid, and in conjunction with the surrounding annulus, it functions as a shock absorber. Vertical loads cause the nucleus to distort uniformly in a circumferential direction, which subsequently results in distortion of the annular envelope and tension in the collagen fibers of the annulus. The healthy lumbar disk is extremely resilient to vertical loading; in fact, the bony vertebrae undergo fracture before there is evidence of disk injury.

There have been numerous investigations of the changes in intradiskal pressure during a variety of lumbar spine postures and activities (9,10 and 11). This information has been useful in increasing our understanding of the biomechanics of the spine and its ergonomic applications. It is uncertain what the relationship between disk loading, disk injury, disk degeneration, and low back pain might be (12).