Artificial Disc Replacement in Degenerative Disc Disease

Essay

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in **Orthopedic Surgery**

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ANATOMY OF THE LUMBER VERTEBRA

Development of the bony spinal column

Development of the spine column begins in the 4th week of gestation, when cells of the sclerotomes surround the spinal cord and notochord. These cells form a mesenchymal column, which retains its segmental origin, and its block are separated by areas of less density.

This process is followed by the proliferation and condensation of the sclerotomal segments and their extension into subjacent intersegmental tissue, binding the caudal half of one sclerotome to the cephalic half of the superior one. The vertebral body is intersegmetnal in origin.

The intervertebral disk is mesenchymal in origin and is derived from the tissue between the cephalic and caudal portions of the original sclerotome. Rather, it fills the space in between what eventually become two precartilaginous vertebral bodies. Although the portion of the notochord in the region of the vertebral body regresses, the portion in the region of the intervertebral disk persists and enlarges. When the persistent notochord lateral undergoes mucoid degeneration, it becomes the nucleus pulposus and is surrounded by the circular fibers of the annulus fibrosus.

Anatomy of the vertebral column

For the development of the artificial disc, first a clear view of the relevant anatomy of the vertebral column is required. The three basic functions of the vertebral column are to transmit load, allow movement, and protect the spinal cord. The vertebral column is a strong flexible rod carrying the weight of the head, chest, abdomen and its contents and arms. It is the central support for the upper body, it makes it possible to walk upright and serves as a point of attachment for the ribs. The human vertebral column is build out of 33 vertebrae. The 24 mobile vertebrae are separated by intervertebral discs. The column is divided into five sections; the cervical section (seven mobile vertebrae, C1-C7), the thoracic section (twelve mobile vertebrae, T1-T12), lumbar section (five mobile vertebrae, L1-L5), sacral section (five fused vertebrae) and coccygeal section (three to four fused vertebrae).

The combined intervertebral discs account for one fourth o the total length of the column above the sacrum. In the lumbar section the discs account for one third, in the thoracic section for one fifth and in the cervical section for two fifth of the total length of the section.

When looking at the spine in the frontal plane, it appears straight and symmetrical. In the sagittal plane there are four normal curves, convex anteriorly (lordosis) at the cervical and lumbar levels, and convex posterior (kyphososi) at the thoracic and sacrococcygeal levels. In the cervical and lumbar section, the curve is to the shape of the intervertebral discs, in the thoracic section due to the shape of the vertebrae.

These curves give the spine increased flexibility, and allow load bearing and shock absorption.

One of the advantages of a curved lumbar spine lies in the resilience. By being curved, the lumbar spine is protected to an appreciable extent from compressive forces and shocks. In a straight lumbar spine, compressive fore would be transmitted through the vertebral bodies and intervertebral discs, and the only mechanism to protect he lumbar vertebrae would be the shock absorbing capacity of the intervertebral discs.

In contrast, in a curved lumbar spine, compressive forces are transmitted through the posterior ends of he intervertebral discs while the anterior ends of the vertebral bodies end to separate. In other words, compression tends to accentuate the lumbar lordisos. This tendency will tense the anterior ligaments which, in turn, will resistant the accentuation. In this way, some of the compressive force is directed into stretching the anterior ligaments instead of being transmitted into the next vertebral body.

Anatomy of the vertebrae

A vertebra consist of an anterior block of bone, the body, and a posterior bony ring, the neural arch, containing articular, transverse and spinous processes. The transverse and spinous processes serve as points for attachment of he spinal muscles and ligaments. The two superior and the two inferior articular processes articulate with the adjacent vertebra and are also called articular facets. The body is a roughly cylindrical mass of cancellous bone with a shell of cortical bone. Its superior and inferior surfaces, slightly concave, are the vertebral endplates. The thoracic vertebrae have articular facets for the ribs. The size of the vertebrae is increasing from cervical to lumbar.

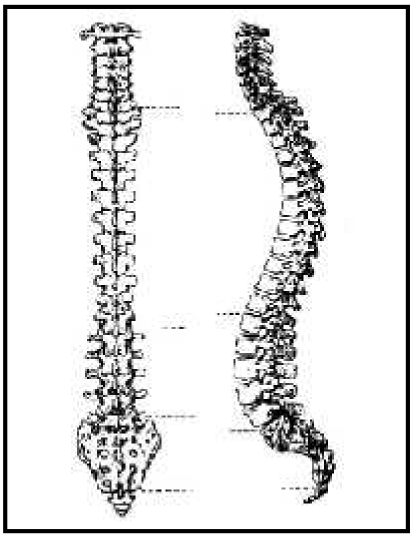

Fig. (1): The human vertebral column
left: frontal view,
right sagittal view.

The movements of the spine depend on the shape and position of the articulating processes. The orientation and geometry of the facet joints are different for the different sections. The orientation of the joints is only approximate.

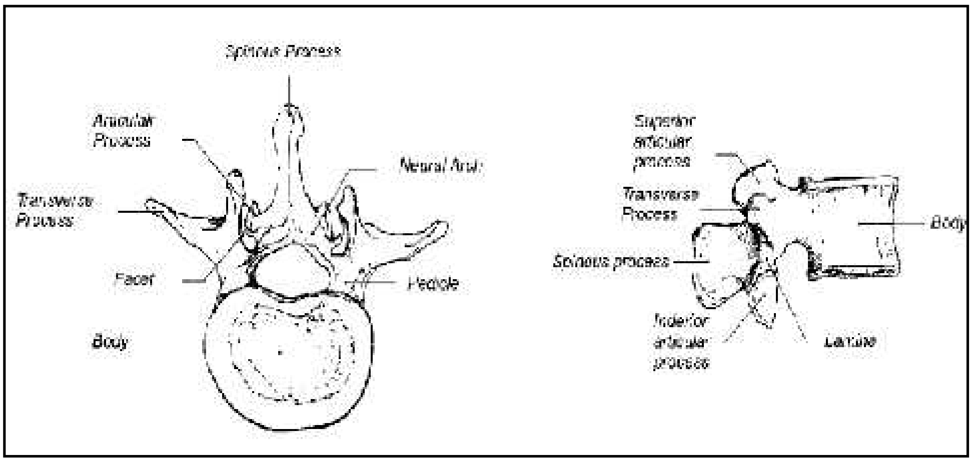

Fig. (2): Anatomy of a vertebra

The exact orientation varies in the sections and also varies in different persons.

Anatomy of the intervertebral disc

The intervertebral disc is composed of the nucleus pulposus, the annulus fibrosus and two cortical endplates. The total water content of the intervertebral disc ranges from 70 to 90%. It is highest at right and tends to decrease with age.

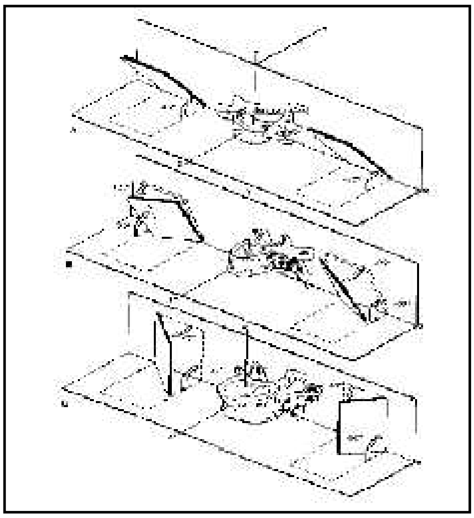

Fig. (3): Orientation of the facet joints. A: Cervical, B: Thoracic, C: Lumbar

Anatomy of the intervertebral disc

The intervertebral disc is composed of the nucleus pulposus, the annulus fibrosus and two cortical endplates. The total water content of the intervertebral disc ranges from 70 to 90%. It is highest at birth and tends to decrease with age.

The nucleus pulposus is located in the center of the disc. It is composed of a loose network of collagen fibers that lie in a mucoprotein gel containing proteoglycans (PG). the PG retain the water in the disc. In an adult, the water content of the nucleus pulposus is 80-85%. The PG-content is 60-65% dry weight, the collagen content is 30% dry weight. In lumbar and cervical section the size (about 30 to 50% of the total size of the intervertebral disc) and the swell capacity is higher than in the thoracic section.

The annulus fibrosus forms the outer boundary of the disc. It is composed of collagen fibers in concentric laminated bands. The fibers run in the same directions (30^o to the disc plane) in a given band but in the opposite direction in the adjacent bands. The fibers are attached to the cartilaginous endplates in the inner zones and to the osseous tissue of the vertebral body in the peripheral zone (Sharpey's fibers). The water content of the annulus fibrosus is 60-70%, the PG-content 20% dry weight and the collagen content is 50-60% dry weight.

In general, in a healthy intervertebral disc the water and PG-content are decreasing while the collagen content is increasing from center to border.

The cartilaginous endplates are composed of hyaline cartilage. The water content is 55%, the collagen content 75-80% dry weight and the PG-content 10-15%.

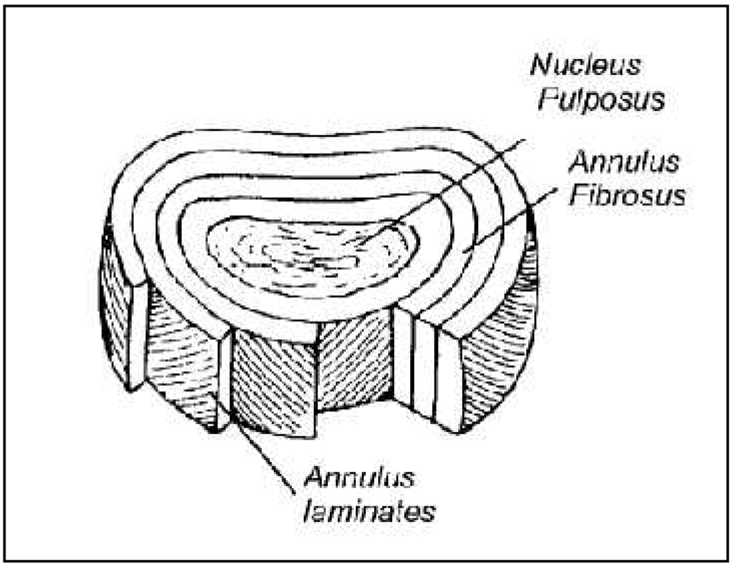

Fig. (4): The intervertebral disc.

The vertebral end plate provides a comparable function to the subchondral bone plate in a synovial joint to disperse the load to the adjacent nucleus pulposus and annulus fibrosus. However, the vertebral end plate, unlike the subchondral bony plate in which no fluid exchanges between the joint cavity and subchondral bony sinusoids, permits fluid diffusion between vertebral sinusoids and the nucleus pulposus and annulus fibrosus. This fluid exchange through the vertebral end plates plays a major role in eh nourishment of the largest vascular structure of the disc. When the disc is loaded on axial compression, the vertebral end plate is the weakest structure among the three component structures of the disc.

The average dimensions of the male endplates were 35.8 mm (sagittal) and 53.7 mm (maximum transverse).

The female endplates were an average of 10% smaller (31.9 mm, 48.1 mm, respectively).

Vascular supply:

I. Arterial supply of the motion segment:

Each lumbar segment is supplied by a paired et of lumbar arteries arising from the aorta. The exception is L5,m which receives its paired arterial supply from the internal iliacs (the ilio-lumbar arteries).

As the lumbar arteries pass posteriorly from the aorta, they do so deep to the sympathetic trunk, hugging the mid point of the vertebral body and psoas and providing a rich network of blood supply to each vertebral segment.

At the level of vertebral foramen these terminal branches to the lumbar segmental arteries arises:

1. Anterior branch to anterior abdominal wall following the anterior aspect of the transverse processes and then lying on the quadrates lumborum.

2. An intermediate branch (spinal artery) that penetrates the foramen and supplies the walls and contents of the spinal canal.

3. A posterior branch (muscular arteries) that passes posteriorly at the lateral edge of the pars interarticularis just proximal to this location at the pars, articular branches are given off. The location of this posterior branch adjacent to the lateral border of the pars interarticularis.

II. Venous supply of the motion segment:

The valveless venous system inside the spinal canal and around vertebral bodies constitutes Batson's plexus, there are thee components of the Batson's plexus:

1. Internal venous system

Within the spinal canal lies the following:

- Anterior internal vertebral veins (AIVV) on the posterior surface of the vertebrae. The basivertebral veins drains into this pat of the system.

- Posterior internal vertebral veins (PIVV) on the anterior surface of the lamina (posterior part of the canal).

- Anastomative veins connect the two systems of the internal venous system, representsa continuous venous pathway from the sacrococcygeal regions to the base of the skull.

2. External venous system

Longitudinally traveling veins lie

- Anterior to the vertebral bodies
- On the outer aspect of the lamina (post. Ext. vertebral plexus).
- On the outer aspect of the transverse process.

3. Connectors

There is arch anastomotic system of veins connecting the internal to the external vertebral system and connecting both part of the vertebral venous system to the vena cava circulation.

It consists of the following:

- Basivertebral branches that pass laterally and forward to penetrate the vertebral bodies.
- Radicular branch of veins that lie with the spinal canal (intervertebral veins).
- Post anastomotic channels that penetrate ligamentum flavum.

- Anastomotic links between AIVV and PIVV within the spinal canal.

This rich venous plexus surrounding the spinal structures is an alternate route to the inferior vena cava system. by raising the intra abdominal pressure or obstructing the IVC in some other fashion, blood flow will go through Batson's plexus into the spinal canal, vertebral bodies, discs or posterior elements.

It is for this reason that proper positioning of the patient is an important step in preparing for lumbar microsurgery.

Anatomy of the ligaments

The ligaments are uniaxial structures. There are seven ligaments of the spine.

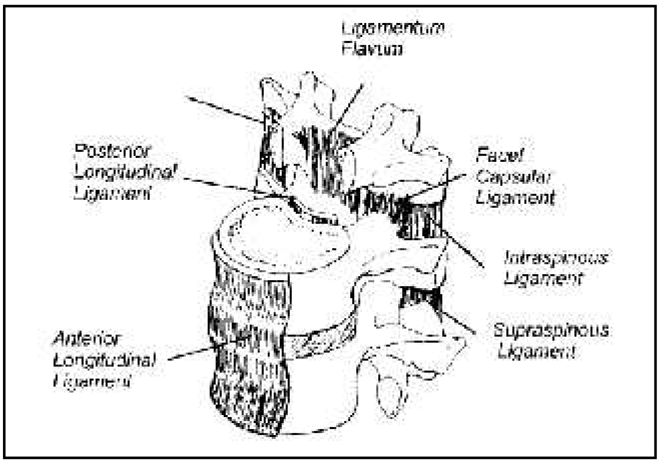

Fig. (5): Motion segment with ligaments