Transverse axial tomography of the spine

Part 1: Axial anatomy of the normal lumbar spine

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The authors describe the technique of transverse axial tomography of the spine and give a detailed description of the axial anatomy of the normal lumbar spine from L-4 to the sacrum. They demonstrate a specific repetitive pattern of intraosseous and articular segments, and stress the importance of the articular processes in shaping the vertebral canal and the intervertebral foramina. The authors believe axial tomography to be a simple, noninvasive radiological technique that allows cross-sectional visualization of the vertebral canal and articular processes in the living patient.

KEY WORDS • transverse axial tomography • articular process • articular segment • intraosseous segment • intervertebral foramina • vertebral canal

Technique

The Toshiba tomographic unit* was used for diagnostic spinal tomography. The basic unit consists of an x-ray tube and film cassette placed at opposite ends of an eccentric C-arm which rotates around the supine patient in a 220° arc. The axis of rotation of the C-arm is in the spinal axis of the patient. The film cassette is placed perpendicular to the spine while the x-ray tube is angled 20° to the spine. The distance from the tube to the spine to the cassette is fixed so that the magnification is constant for all examinations. The magnification has been measured at 33%; tomographic cuts are 3 mm thick.

The operator accurately positions the patient for tomography by lining up skeletal landmarks, such as the iliac crests, with centimeter marks on the examination table. The constant magnification and reproducibility of the tomograms make possible accurate comparison of films at any given level with films from a previous examination in the same patient, or with those taken at a similar level in a different patient.
Transverse axial tomography of the spine

Anatomy of the Lumbar Spine

Previous descriptions of the axial anatomy of the lumbar spine have been limited to the study of axial photographs or radiographs of isolated vertebral bodies. In the articulated spine, the spinal canal appears as a repetitive series of intraosseous and articular segments (Fig. 1); thus, examination of disarticulated vertebral bodies alone cannot adequately demonstrate the geometric configuration of the spinal canal.

The intraosseous segment of the lumbar canal is formed by the continuous bony rim of the vertebral body, pedicles, pars interarticularis, laminae, and spinous process. Examination of the articulated spine reveals that only a small portion of the vertebra and canal is included in the intraosseous segment. The much larger articular segment includes the intervertebral disc, the intervertebral foramina, the articular processes, and the dorsal arch. These are the major anatomical components that give rise to symptoms and signs comprising the lumbar disc syndrome, lumbar stenosis, and spondylosis. Although not ignored, this segment of the canal has not been recognized or presented anatomically as a distinct entity.

The cross-sectional anatomy of the normal lumbar spine, as studied by means of axial tomography, will be described as a continuum of intraosseous and articular segments through successive vertebral levels, in order to illustrate and emphasize the constantly changing geometric configuration of the spinal canal. This description is limited to the lower lumbar spine from the upper level of L-4 to the sacrum. Each radiograph is typical of a specific level of the canal and is a representative selection from the group of 50 normal patients examined.

The L-4 Intraosseous Segment

The L-4 vertebral body is demonstrated ventral to the spinal canal (Fig. 2). The vertically-oriented pedicles originate from the dorsolateral edges of the vertebral body. At this level, the canal is formed ventrally by the posterior edge of the vertebral body, and ventrolaterally, laterally, and dorsolaterally by the pedicles. The ligamentum flavum forms the dorsal wall. More caudal, the dorsal arch of L-4 attaches to the pedicles in the region of the pars interarticularis (Fig. 3). The dorsal arch is composed of the spinous process in the midline and the lateral ventrally divergent laminae. The laminae extend into the inferior articular processes of L-4 further laterally and caudally. The intraosseous segment is triangular in shape with an acute interlaminar angle at the apex of the dorsal arch.

The L-4 Articular Segment

The rostral portion of the L-4 articular segment maintains the triangular configuration characteristic of the L-4 intraosseous segment (Fig. 4). The ventral border is indistinct at the lower section of the L-4 vertebral body where the L-4 intervertebral disc becomes the ventral wall of the canal. The dorsolateral walls of the canal are composed of the inferior articular processes of L-4 laterally and the junction of the articular processes with the laminae slightly dorsally and medially. In the more caudal portion of the articular segment of the canal, the superior articular processes of L-5 border the intervertebral foramina dorsally while forming the most ventral point of the lateral walls of the canal (Fig. 5).

At L-4, the medial borders of the articular processes abutting on the canal have a straight or very slightly medially convex curve. The lateral walls diverge symmetrically from the dorsal laminar angle to the intervertebral foramina.

The L-5 Intraosseous Segment

The pedicles of L-5 delineate the L-5 intraosseous segment of the canal. They are less distinct and shorter, both anatomically and on axial tomography, than the pedicles of L-4.
or of the other lumbar vertebrae (Fig. 6). The ventrolateral and lateral walls of the L-5 intrasosseous canal are also formed by the superior articular processes of L-5 which extend directly dorsal from the pedicles. The intrasosseous canal of L-5 has a triangular configuration. The base is formed by the body of L-5. The lateral walls are constituted by the pedicles, pars interarticularis, and superior articular processes which merge into the apex by way of the laminae and spinous process.

**The L-5 Articular Segment**

As the articular segment of the lumbosacral canal enlarges caudally, the dorsal arch becomes rounded (Fig. 7). The inferior articular processes and laminae form the lateral, dorsolateral, and dorsal walls. The medial surfaces of the articular processes are slightly concave and blend imperceptibly into the arch, making the posterior wall of the canal smooth, symmetrical, and distinct in shape. As the L-5 articular segment of the canal enlarges caudally, the ventral half widens into the intervertebral foramina, while the inferior articular processes of L-5 are slightly dorsal and medial (Fig. 8). The lateral walls of the canal are formed almost entirely by the inferior articular processes of L-5, although the superior articular processes of S-1 form the extreme ventrolateral corners. The transition across the interfacet joints is smooth, and a gentle curve replaces the acute
Transverse axial tomography of the spine

FIG. 6. Tomogram (left) and line drawing (right) showing section through the intraosseous segment of L-5. See previous figures for abbreviations.

FIG. 7. Tomogram (left) and line drawing (right) showing section through the L-5 intervertebral disc in the superior portion of the L-5 articular segment. See previous figures for abbreviations.

The laminar angle so typical of the other lumbar dorsal arches. The medial aspects of the inferior articular processes of L-5 have a concave contour which gives a slightly outwardly-bowed configuration to the normal lumbosacral canal.

The caudal limit of the articular segment of the lumbosacral canal is marked by the junction of the superior articular processes of S-1 with the bone of the sacrum (Fig. 9). The articular segment of the lumbosacral canal extends 1.0 to 1.5 cm below the level of the intervertebral disc.

The S-1 Intraosseous Segment

At this level, the articular process is definitely superior and exterior to the true sacral canal. The sacral intraosseous canal has a triangular configuration (Fig. 10) which decreases progressively in size through the sacrum. The bony spinal canal narrows acutely so that the widest segment of the lumbosacral canal is at the base of the superior articular processes of the sacrum.

Discussion

Cross-sectional examination of disarticulated lumbar vertebrae compared to axial tomography of the intact lumbar spine reveals several important points concerning the anatomy and configuration of the lumbar canal that need further emphasis and clarification.

The size of the pedicles is not constant, but diminishes progressively from L-1 to the sacrum. At L-4, the pedicles are still a distinct strut forming the ventrolateral, lateral, and dorsolateral walls of the L-4 intraosseous canal, while at L-5 they have decreased in height, so that their contribution to the composition of the wall of the intraosseous canal is at the base of the superior articular processes of the sacrum.
The relative position of the articular processes forming the joints is constant. The superior articular processes are always slightly caudal, ventral, and lateral to the inferior articular processes above. The medial surfaces of the apophyseal joints abutting on the canal are normally smooth. Since the articular processes form the dorsal borders of the intervertebral foramina, their contained nerve roots are particularly vulnerable to any change in the articular configuration.

The lumbar spinal canal has previously been represented as a gradually and continuously expanding triangular tube. This concept of the canal, obtained from studies of serial intraosseous segments of disarticulated lumbar spines, ignores the true role of the articular segments as defined in this report; in fact, one would reach the same conclusion by studying only the serial axial tomograms of the intraosseous segments. When the larger intervening articular segments are included, our concept of the spinal canal is modified from that of a smoothly and continuously enlarging triangular space to that of a sequential space whose geometric configuration is constantly changing with the repeating pattern of intraosseous and articular segments (Fig. 11). In addition, each of these segments from L-1 to the sacrum has a characteristic configuration which is constant for any level. However, each segment contains a variable portion of the articular processes; these play a predominant role in forming the walls and determining the shape of the canal, as well as determining its vulnerability to congenital or degenerative bone changes.

Fig. 11. Series of tomograms of the lumbar spine from L-4 to S-1, showing the variation of the canal shape from level to level. Tomograms are 1 cm apart and 2 mm thick. If b, c, and h are examined alone, the canal appears to be triangular. When the intervening articular segments are studied, especially at L5–S1 (f and g), there is a distinct change in shape. a. Upper body of L-4. b. Osseous segment of L-4. c. L4–5 disc. d. L4–5 articular segment. e. Osseous segment of L-5. f. Upper portion of the articular segment of L5–S1 at the level of the intervertebral foramen. g. Lower level of the articular segment of L5–S1. h. Osseous segment of S-1.
Transverse axial tomography of the spine

References


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