

Lumbar Epidural Anatomy

A New Look by Cryomicrotome Section

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The anatomic findings from cryomicrotome sections of 38 cadaver lumbar spines are reported. The technique produces high-resolution planar images of undisturbed epidural anatomy. Several observations differ from previous reports that used methods more prone to artifact. The epidural contents are found in circumferentially and metamERICALLY segmented compartments, rather than in a uniform layer. Large areas of the dura are directly in contact with the spinal canal wall. The steeply arched ligamenta flava are fused in the midline to a variable degree. The space anterior to the dura is filled with veins and is isolated from the rest of the epidural space by a membranous lateral extension of the posterior longitudinal ligament. This membrane and a midline posterior fat pedicle are the only observed potential barriers to the spread of epidural solutions. These findings may be important in understanding the mechanics and pharmacokinetics of solutions injected into the epidural space and in refining techniques for needle and catheter placement. (Key words: Anatomy: spine. Anesthesia: regional. Anesthetic techniques: epidural.)

THE ANATOMY of the epidural space has great relevance to the anesthesiologist, for this is a frequent site of needle, catheter, and drug placement for anesthesia, analgesia, neurolysis, and electrostimulation. Nonetheless, little attention has been paid to the details of its structure, which in turn influences the mechanics and the pharmacology of drugs injected in the spinal canal. Spinal anatomy has been a focus of attention by surgeons and radiologists, especially in the areas of the disc, ligaments, and joints.^{1,2} The areas of importance to the anesthesiologist, including the distribution of the epidural contents and the relationship of the dura to the surrounding rigid structures, have been less well investigated, in part because of the inadequacy of available methods. Dissection is unavoidably a destructive process. Disruption of the balance of forces across the flexible walls of the thecal sac^{3,4} and epidural veins and within the uniquely semifluid⁵⁻⁸ epidural fat make it impossible for dissection,^{9,10} even in surgical subjects,¹¹ to accurately reveal natural anatomy. For example, the ligamentum flavum is under tension and retracts when cut,¹²⁻¹⁴ and the epidural fat and dura fall away when the

epidural space is opened.¹¹ Similarly, the introduction into the epidural space of radiologic contrast,¹⁵⁻¹⁸ air,^{19,20} or resins^{21,22} only provides images of the way in which an observable mass can distort the native epidural anatomy.

A new method, the study of cryomicrotome sections of cadaver material frozen *in situ*, allows a detailed examination of epidural anatomy without disruption of the forces that determine the distribution of soft tissues in the spinal canal. This paper reports observations made by this technique, suggesting that undisturbed epidural anatomy differs significantly from that reported previously.

Materials and Methods

Cryomicrotome images were produced as part of an ongoing project of the Department of Radiology, Medical College of Wisconsin. Thirty-eight bodies were obtained through a donor program. The average age was 62.6 yr (range 10-87 yr), and 23 were male. To avoid tissue changes, freezing was begun within 15 h of death, and the lumbar spine was removed intact only after freezing was complete. A heavy-duty sledge cryomicrotome (model 2250, PMV Inc., Bromma, Sweden) was used to reveal sectional anatomy. The device maintains the tissue block at -20° C while shaving with a heavy blade capable of cutting bone, thereby removing tissue from the block in 20-μm increments. High-resolution color photographs were made of the unstained block at 1-mm intervals using ASA 25 film and an Olympus OM-2 macrophotography system. Projection or examination under a 10× binocular microscope allowed detailed study of the photographic images. The plane of sectioning was axial in 7 specimens, sagittal in 24, and coronal in 7. In none of these was there apparent congenital, traumatic, metastatic, or advanced degenerative disease. Thirteen of the specimens were thawed to allow magnetic resonance imaging (data not reported here) and were refrozen prior to sectioning.

The terminology for the intervertebral root canal is adopted as recommended by Rauschnig.²³ The epidural space is considered to include the area within the fibrous and bony walls of the spinal canal but outside the dura. There is no convention as to where in the root canal the epidural space stops and the paravertebral space begins. In this discussion, the narrowest portion of the intervertebral root canal will be deemed the boundary of the epidural space.

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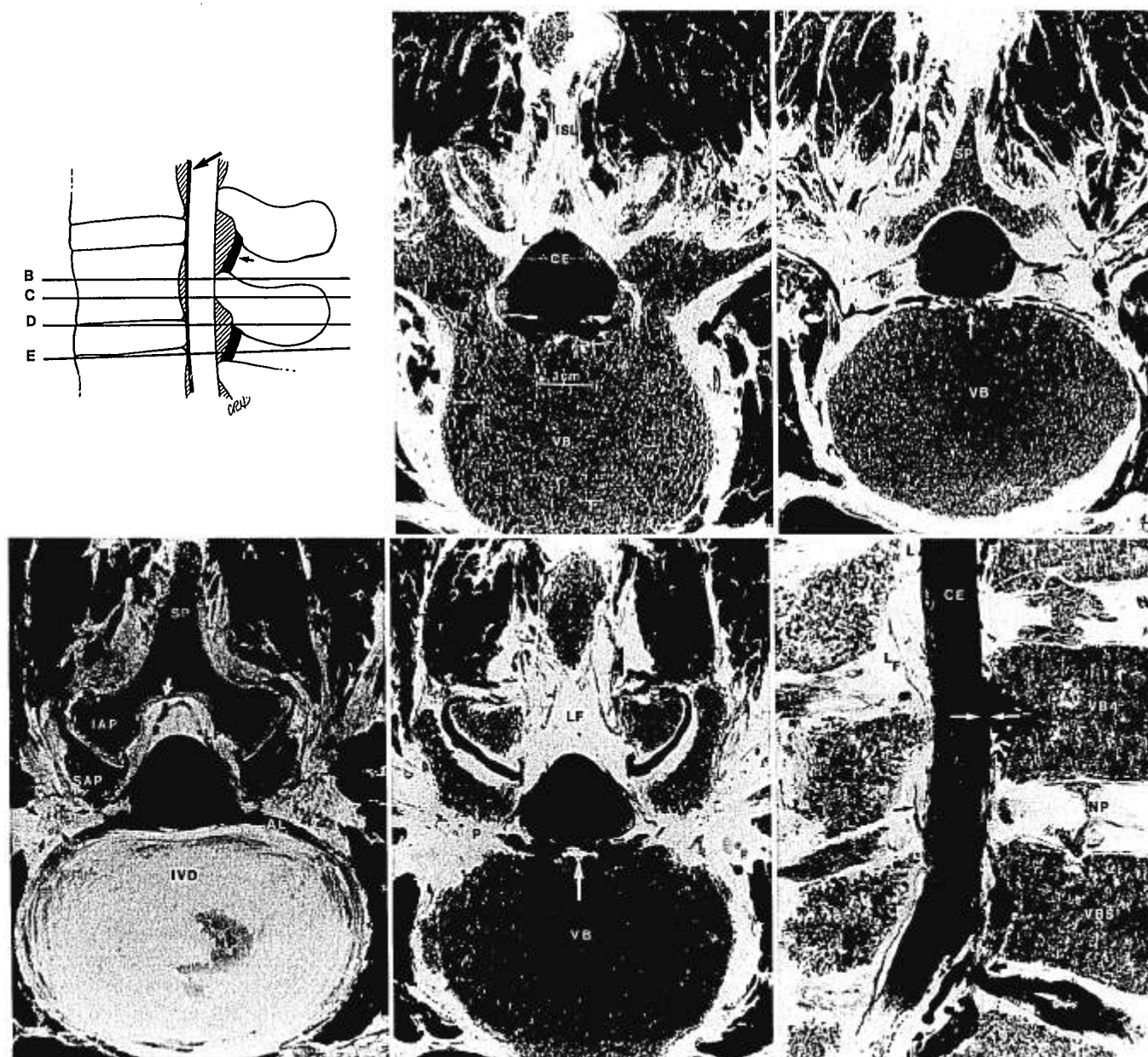


FIG. 1. Sections of the lumbar spine of a 54-yr-old man. *A* (top left): Midline sagittal drawing demonstrating the approximate levels of the axial sections in figures 1B–1E. The crosshatched areas are the anterior and posterior epidural compartments. The anterior dura and the PLL are fused (long arrow). The short arrow identifies a ligamentum flavum. *B* (top center): Axial section through the caudal portion of the pedicles of the third lumbar vertebra. Extensive areas of bone contacting dura are demonstrated. Cortical bone appears white, and cancellous bone appears red and granular. *C* (top right): Axial section caudad to figure 1B, through the third lumbar vertebra and the nerve root canal of the third lumbar nerve roots. The lateral epidural compartments contain nerves and fat, and the anterior compartment contains veins (appearing black) and fat. The PLL (black arrows) is fused with the dura. Dense connective tissue (white arrow) is a midline extension of the adjacent disc. *D* (bottom left): Axial section caudad to figure 1C, through the L3–L4 disc. The anterior compartment of the epidural space is absent as the annular ligament of the disc fuses with the PLL and dura. The posterior fat-filled epidural compartment is enclosed by the ligamenta flava and the dura, and is not continuous with the lateral compartment. A vessel can be seen entering the posterior epidural compartment (white arrow). Lateral to the dorsal root ganglion, the nerve roots disperse into multiple, loosely packed fascicles (area marked by black arrows) before reforming as the common spinal nerve.* *E* (bottom center): Axial section caudad to figure 1D, through the fourth lumbar vertebra at the cephalad edge of the pedicles. The ligamenta flava form a steeply arched roof over the posterior epidural compartment. The segmental nerve fascicles have joined to form two or three bundles, which more distally will completely fuse to form the segmental nerve. The anterior epidural space is divided sagittally at this level by midline connective tissue (arrow) which extends from the disc. (*Kostelic JK, Haughton VM, Sether LA. Anatomy of the proximal lumbar spinal nerves in the neural foramen. Clin Anat (in press).)

FIG. 2 (*bottom right*). Midline sagittal section through the fourth and fifth lumbar vertebrae and parts of the third lumbar and first sacral vertebrae, showing the posterior epidural compartments (thin black arrows). The dura is joined with the PLL (white arrows) cephalad from the L4–L5 disc, but separate caudad from that disc. The space anterior to the dura is nearly filled with veins except caudad to the L4–L5 disc, where a fat-filled anterior epidural space develops. Degenerative changes are apparent in the discs of this 65-yr-old man, including an extrusion of L5–S1 nucleus pulposus through the annular ligament into the spinal canal (heavy black arrow).

Results

Cryomicrotome sectioning and photography produces images allowing the sharp resolution of structures as small as 100 μm . The observations reported below are consistent findings in all the spines examined, unless otherwise mentioned. In specimens not thawed after harvest, there is no free blood or fluid in the tissues. In contrast, specimens that had been thawed showed free fluid in the epidural space. This artifact results from drainage of the thawed CSF from the open end of the dura, after which the dura falls away from the surrounding structures.

The distribution of the epidural space circumferentially around the dura depends on the longitudinal site of the axial section (fig. 1A). Axial cuts through the pedicles at their caudad margin (fig. 1B) show virtually no contents in the epidural space except veins anteriorly. Between the pedicles (fig. 1C), an epidural compartment opens up lateral to the dura, which includes the medial intervertebral nerve root canal and contains fat, nerve roots, and vessels. Posteriorly, an epidural compartment containing fat forms between the middle of one lamina and the cephalad edge of the next lower lamina, roofed by the inferior portion of the lamina (fig. 1D) and the ligamenta flava (fig. 1E). Midsagittal views (fig. 2) show this compartment to have maximum anterior/posterior dimensions at its cephalad end.

KEY TO FIGURES

AL = annular ligament
CE = cauda equina
IVD = intervertebral disc
d = dorsal root ganglion
IAP = inferior articular process
SL = interspinous ligament
L = lamina
LF = ligamentum flavum
NP = nucleus pulposus
P = vertebral pedicle
PLL = posterior longitudinal ligament
SAP = superior articular process
SP = spinous process
VB = vertebral body
v = ventral root

Note: Bilateral structures in most cases are labeled or highlighted with arrows on one side only.

Between the various compartments are areas in which the dura is directly apposed to bone or ligamentum flavum. Specifically, the lateral compartments are separated by the intervening pedicle in contact with the dura. Similarly, the posterior compartments are separated by dural contact with bone beneath the cephalad half of each lamina. Finally, the lateral and posterior compartments are discontinuous, separated by areas of contact of dura with the ligamentum flavum as it wraps around the medial aspect of the facet joint (figs. 1D and 1E). There is thus a repeating metameric segmentation of the epidural contents in the longitudinal axis (fig. 3).

The ligamenta flava have a right and left portion, fused in the midline to a variable degree. On occasion, there is a midsagittal gap (fig. 4). The angle at which the ligamenta flava meet, as viewed in axial section, is 90° or less. A thin, brown, fibrous-appearing layer is seen on the inner aspect of the ligamenta flava (fig. 4), although it is not present in all sections and may be discontinuous when present (fig. 1D). Rarely, this layer can be seen to fuse with the epineurium of the dorsal root ganglion (fig. 5).

The epidural space contains nerves and veins but is mostly fat. In the posterior compartment (figs. 1D, 1E, 2, and 4), this fat is homogeneous and without any apparent fibrous septation. When fluid enters the epidural space in the thawed and refrozen specimens (fig. 6), the triangular posterior fat pad falls away from the walls of the space but remains adherent at its apex by a pedicle-like attachment to the site at which the ligamenta flava abut in the midline. A vessel is usually seen entering the epidural fat through this connection (figs. 1D and 1E). The dura separates from surrounding structures in the thawed specimens except where it is adherent to the posterior longitudinal ligament (PLL). No posterior midline dural fold is evident in any specimen.

In the lateral epidural compartment, the fat is lobulated by septae (figs. 1C, 1D, 7, and 8). In most specimens, a plane of septation extends from the sheath of the exiting nerve root to the PLL (figs. 1C and 7). The PLL is closely applied to the anterior dura and blends into the annular ligament in axial sections at the level of a disc (figs. 1D and 4). Adjacent to a disc, the space between the PLL and vertebral body is occupied by nonfatty connective tissue (figs. 1C, 1E, and 7). The ligament bridges the concavity of the posterior aspect of the vertebral body, creating a compartment between the ligament and body (figs. 1B, 1C, 1E, and 2). This space is virtually filled with a

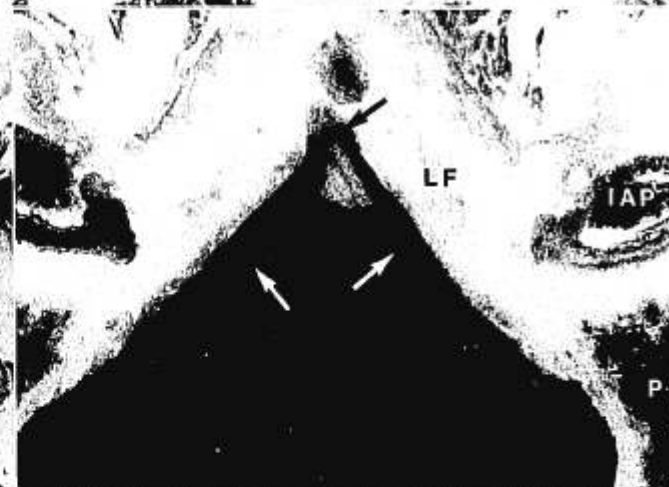
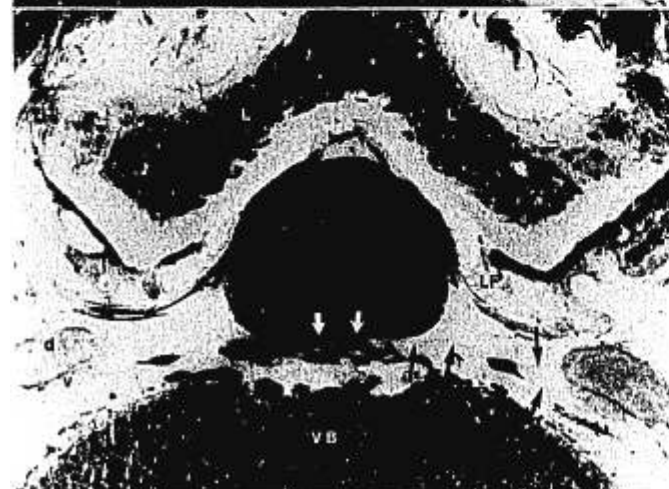
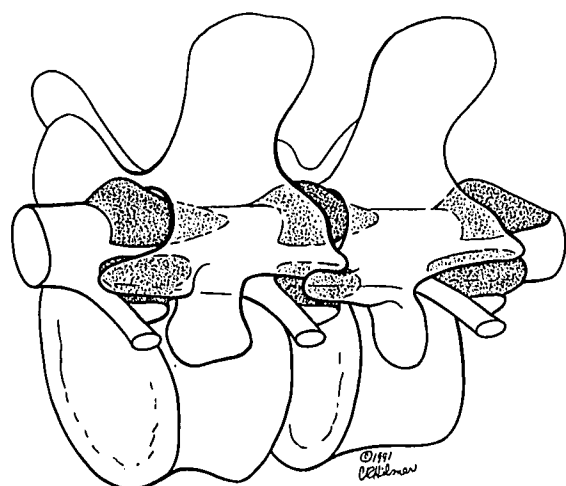


FIG. 3 (top left). A drawing of the compartments of the epidural space (stippled). The epidural contents are discontinuous circumferentially, and repeat metamerically. Where no contents are represented, the dura is in contact with the spinal canal wall. The pedicles are concealed behind the transverse processes.

FIG. 4 (top right). Axial section through the L1-L2 disc, showing the incomplete fusion of the ligamenta flava in the midline. The facet joints are dark areas between the superior and inferior articular processes (SAP and IAP). The posterior longitudinal ligament (heavy arrows) is fused with the dura and annular ligament. The lateral intervertebral ligament⁴⁴ is apparent (thin arrows) but was absent in adjacent sections.

FIG. 5 (center left). Axial section through the second lumbar vertebra showing the internal fibrous lining of the ligamentum flavum joining (at the arrow) the epineurium of the dorsal root ganglion. This was not apparent at sections either 1 mm above or below this section.

FIG. 6 (center right). When thawing of the specimen allows fluid to enter tissue planes, the posterior epidural fat separates from the canal wall except at the midline, where it is tethered by a pedicle (black arrow). The fat has also separated from the dura (white arrows).

FIG. 7 (bottom left). Axial section through the fourth lumbar vertebra and the root canal of the fourth lumbar spinal nerve. A plane is apparent (black arrows) extending from the PLL (white arrows) and splitting to envelop the dorsal root ganglion and ventral root, isolating the veins anteriorly.

FIG. 8 (bottom right). Coronal section through the pedicles of the third, fourth, and fifth lumbar vertebrae. The nerve roots are seen exiting the spinal canal in close contact with the caudal aspect of the pedicles. The section is somewhat oblique, with the right side being cut more posteriorly and therefore showing no nerve root but revealing the anterior lip of the ligamenta flava. The cut edge of the dura (arrows) is in continuity with fibrous tissue extending laterally into the nerve root canal, probably representing the fascia of the PLL.

venous plexus that is the origin of the basivertebral vein, which may arise as a deep invagination of the plexus into the vertebral body. Few veins are seen posterior to the plane connecting the PLL and the nerve root. Only caudad to the L4–L5 disc do the PLL and dura part, creating a fat-containing capacious anterior epidural space as the dural sac assumes a more posterior position in the spinal canal, separating from the PLL (figs. 2).

There was no evidence of a fibrous barrier across the intervertebral neural canals, although a narrow fibrous band could sometimes be seen adjacent to the superior edge of the pedicle (fig. 4). Coronal sections through the canals (fig. 8) showed the epidural space to be widely open on its lateral aspect.

Discussion

CRYOMICROTOME SECTIONING

The limitations of the methods used in this study relate to the changes that take place upon death. Typically, cerebrospinal fluid pressures decrease,^{19,24} and venous pressures can be expected to increase.²⁵ To some extent, at death the veins may expand at the expense of the dural space. This is probably a small aberration, since computed tomographic^{26,27} and magnetic resonance^{2,28} images confirm the relative sizes and positions of epidural structures seen on cryomicrotome sections. Alterations with freezing are minor, with linear dimensions in tissues changing by about 2% or less.²⁹

The use of cryomicrotome sections for the study of anatomy frozen *in situ* avoids the shortcomings of other methods that have been used to explore the epidural space. The limitations of dissection result in reports such as Cheng's⁹ that "the entire epidural space is filled with a quantity of loose adipose areolar tissue," and the statement of Ellis and Feldman⁵ that "the capacity of the epidural space is far greater than that of the subarachnoid space at the same level," contrary to what is seen in the present study, in which freezing preserves the topographic relationships of structures in their native positions. The careful dissections of Parkin and Harrison¹⁰ were done on cadavers in which the tissues had been made somewhat

firm by embalming, and their findings are mostly consistent with the present study.

Other attempts to describe the epidural space have involved the introduction of various substances into the space. Injection of resin,^{21,22} x-ray contrast,^{15–18} or air followed by epiduroscopy^{14,15} will reveal not the normal anatomy but only the manner in which the epidural space may be deformed to accommodate a mass. The dura has been shown to be easily compressible,^{11,3,4} and the same can be assumed for the thin-walled epidural veins.³⁰ Useful images of adjacent hard structures can be produced by such injections into the spinal canal,^{15,16,31} but since the dural sac and veins are compressed and the epidural fat is displaced, little meaning can be derived about the natural anatomic relations of the epidural soft tissues under such conditions. No foreign material was injected in this study. In thawed specimens, the separation of tissues proved to be a useful artifact in delineating patterns of adherence between posterior epidural space tissues.

SEGMENTATION OF THE EPIDURAL SPACE

Depictions of epidural anatomy in anesthesia texts consistently show an epidural space of uniform width completely encircling the dura. The present study shows that the epidural space is empty (a "potential space") in large areas where bone and ligament contacts dura and has contents in segmentally distributed compartments. The appearance of axial sections depends entirely on the level of the section within the segment. These findings are supported by observations using computed tomographic^{26,27} and magnetic resonance imaging.^{2,28} Since the principal tissue within the epidural space is fat, descriptions of its segmental distribution^{10,32,33} provide a further confirmation of the segmentation of the epidural space.

The discontinuous distribution of epidural contents may have important implications for the pharmacokinetics of drugs injected into the subarachnoid or epidural spaces. Because local anesthetics may have considerable affinity for epidural fat,³⁴ drugs administered through a catheter positioned with its tip in the posterior fat compartment may exhibit different absorption and distribution than if

the tip is between lamina and dura, contributing to the variability of response to epidural injections. These anatomic details may be especially important when concentrated solutions of opioid or local anesthetic are used for slow continuous infusion for chronic pain therapy.

Epidural segmentation may also be relevant to the mechanics of the epidural space. The rigid enclosure and isolation of the posterior epidural space, like the pleural cavity and the joint spaces, allows the tissues to generate a subatmospheric tissue fluid pressure³⁵ through the action of the lymphatics and the balance of osmotic and hydrostatic forces across the capillary endothelium (Starling forces).

The epidural space behaves like a Starling resistor,³⁶ with pressures decreasing after injection to a nonzero plateau,³⁷ independent of the volume injected.^{36,38} This may be a result of the apposition of the dura and bone, past which injected fluid must pass to escape the posterior epidural space. The pressure in the rest of the epidural space probably reflects the abdominal pressure because of the extent to which the lateral epidural wall is incomplete (fig. 8) and because of the nonrigidity of the epidural contents.^{4-6,39} Increases in abdominal pressure, such as during a cough, are readily transmitted to the epidural space.⁴⁰

POSTERIOR EPIDURAL SPACE

The paired nature of the ligamenta flava and the acute angle of their intersection is in agreement with other reports.^{2,13} The right and left portions of these ligaments have been reported by some authors to be fully joined in the midline,^{14,28} whereas others have found a midsagittal gap.^{2,10,13} The degree of fusion in the specimens examined for the present report was variable, even at different levels from the same subject, though an actual gap was rare.

The posterior epidural fat appears notably free of any septation or internal structure. Histologic studies have similarly shown this fat to be remarkable for its homogeneous structure and its lack of fibrous content.^{7,41} The specimens thawed before sectioning show that the epidural fat in the posterior compartment freely separates from the ligamenta flava and dura except in the midline. Ramsey reported⁴¹ that the epidural fat of cats is "a free gliding mass" contained in a "delicate smooth capsule . . . unattached to either canal wall or dura," adherent only along the posterior midline. It is likely that these freely separable planes provide a route for the dissipation of injected anesthetic as well as for air and fluid injected during the loss-of-resistance technique for confirming entry into the epidural space. The demonstration of a midline pedicle for the posterior fat pad is consistent with the finding that vessels enter the fat at this site.^{13,14} When an epidural

needle enters the posterior space through the pedicle, it will directly enter the substance of the fat pad where injectate will loculate instead of dissipating. There will be a loss of the firm resistance to injection provided by the ligamentum flavum (possibly absent in the midline) and the interspinous ligament, but injected air will gently return to a well-lubricated syringe, and a catheter will not pass easily. The presence of a midline fat pedicle and the thinning of the ligamentum flavum in the midline may account in part for the reported benefits of the paramedian approach compared to the midline approach for epidural needle or catheter placement.⁴²

Various injection and dissection studies have demonstrated a fold in the posterior dura along the midline.^{11,19-21} This "plicae mediana dorsalis" was not seen in any specimens in the present study and probably reflects an artifact due to dural tethering in the presence of unnatural transmural dural pressures during distention of the epidural space. Such attachments of the posterior dura to the lamina^{10,11,43,44} have been identified in humans but are few and weak compared to the substantial fibrous bands joining the dura anteriorly to the PLL.^{8,10,43}

The structure of the posterior epidural space has been inferred by other authors from its appearance during injection studies. Savolaine *et al.*¹⁸ used computed tomography to produce images of a midline structure with lateral extensions, which they interpreted as connective tissue septae partitioning the posterior epidural space. Their technique involved distention of the space with contrast injected through a catheter that was manipulated to facilitate spread. Considering the cryomicrotome appearance of undisturbed epidural anatomy, it is likely that the midline structures and lateral membranes described by Savolaine *et al.* are simply the epidural fat pad itself with its lateral attenuations, stretched and suspended in a posterior compartment distended by dye, creating an appearance similar to the thawed specimens in this study. Savolaine concedes the absence of apparent membranous structures in the physiologic state as viewed by magnetic resonance imaging.⁴⁵

In a similar way, the "dorsomedian connective tissue band" observed by Blomberg¹⁹ and Blomberg and Olsson²⁰ during epiduroscopy probably represents the deformed posterior fat, stretched between its pedicle and midline dural adhesions by air injected into the plane where the fat is nonadherent. The isolation of injectate to a single half of the posterior epidural space has also been offered as evidence of a midline fibrous barrier.¹⁶ Given the absence of any such structure in the present study, a preferable explanation is that the fat and its pedicle function as an inconstant partition. Finally, the midsagittal lucency on epidurograms^{11,15,16,18} is most likely another manifestation of the fat and pedicle as it excludes

contrast from the posterior midline, although an artifactual "plicae mediana dorsalis" from dural deformation might contribute to creating such a lucency, as others have claimed.^{11,15,16,18} Further confusion on these matters is provided by authors^{14,18,46-48} who refer to the fat contents of the epidural space as an "epidural membrane," perhaps because of its collapsed and dispersed appearance when supporting structures are removed in dissection.

LATERAL AND ANTERIOR EPIDURAL SPACE

The fibrous structure of these spaces determines the spread of injectate and the forces placed upon the tethered nerves and dural sac. Yet this area of epidural anatomy is especially unclear and poorly described in published work. This study shows that the anterior dura is in direct contact with the PLL. By dissection, the two structures have been found to be strongly adherent, especially in the low lumbar area where they are firmly fused.⁴⁹ The joined PLL and anterior dura are seen on cryomicrotome sections to stretch like a bow string between the discs, spanning the vein-filled cavity between it and the vertebral body, creating what Schmorl¹ referred to as a "vascular channel."

The tissue plane seen on axial cryomicrotome sections extending from the PLL to the nerve root was identified in dissections by Trolard in 1893⁴⁴ and subsequently by Schmorl¹ as a fascia that entirely divides the spinal canal in a coronal plane, isolating the anterior epidural space from the rest of the epidural space. The structural importance of this membrane has been documented by its ability to constrain the migration of extruded fragments of disc material, blocking the passage of such material out of the anterior epidural space.⁵⁰ Other authors have described this layer in the cervical spinal canal as the fascia of the PLL^{46,47} and at the lumbar level as the superficial layer of the PLL.⁵¹

The cryomicrotome appearance of the anterior epidural space is distinct from other areas in the spinal canal. It is nearly filled with veins, which rarely cross the plane of the PLL and its lateral membrane, and has minimal amounts of fat, as also found by others.^{10,52,53} One report noted a midline septum dividing the anterior compartment.⁵⁰ In the present study, a midline tongue of connective tissue was seen to extend from the disc, reaching caudad and to a lesser degree cephalad between the PLL and the posterior vertebral body, but this is absent at mid-vertebral levels where no septation is seen. The anterior compartment vanishes at the level of each disc, where the PLL fuses with the annular ligament. Only caudal to the L4-L5 disc is the dura separated from the PLL by abundant epidural fat. The change in anatomy at this level may contribute to the difficulty in blocking the L5 and

S1 nerve roots⁵⁴ by imposing greater barriers for the local anesthetic to penetrate or a larger area into which the drug may disperse and not reach the roots.

Covino and Scott³⁹ differ from most sources in describing an outer endosteal dura lining the walls of the epidural space, as well as the inner (meningeal) dura which makes up the dural sac. Evidence in the present study for this outer dura could be identified in axial sections as a lining on the inner aspect of the ligamenta flava (figs. 1D and 2). It appears incomplete and is often absent. There is occasional evidence (fig. 5) of a fusion of this layer with the nerve sheath in the intervertebral canals, though not in a broad and uniform way as described by those authors.³⁹ The system of tissue planes in the spinal canal may be put into perspective by the embryologic observations of Ludinghausen.⁸ The connective tissues of the spinal canal have a common anlage surrounding the neuraxis. The meningeal pia and dura mater are derived from this formative tissue, as is the "endorachis" that lines the bony and fibrous walls of the canal. Anteriorly, the endorachis thickens to form the PLL, while posteriorly it splits to enclose the epidural fat. Perhaps it is the residua of the embryonic layer that is apparent as a fibrous lining to the ligamentum flavum, a lateral extension of the PLL, and a layer joining the nerve roots to the canal wall. By this view, the compartment anterior to the PLL has an independent embryologic origin, as is also indicated by its distinct appearance.

There was no evidence of either a fibrous "operculum" across the intervertebral canals as seen in dissections by Tinel and Forestier or a fibrous condensation of epidural tissue near the nerve root canal, referred to by Soulie as the "lame epidurale" (see Frykholm⁴⁶ and Sunderland⁵⁵). The observations of these early authors may have been artifacts created by drying and preservation.⁵⁵ Rauschnig²³ observed an incomplete fibrous septum covering the foraminal outlet of the nerve root canal, made up of the fascia of the psoas muscle. This septum was also not apparent in the specimens examined in present study, which therefore reveals no fascial enclosure of the lateral epidural space. This is consistent with the observation of spread of x-ray contrast out the intervertebral root canals.^{15,16,18,31,56} In some axial sections (fig. 4), the lateral intervertebral ligament described by Trolard⁴⁴ can be seen, superior and adjacent to the pedicle and inserting upon the superior articular process. This narrow slip of fibrous tissue is not likely to constrict flow through the nerve root canal, although it might play a role in nerve root compression.

CONCLUSION

Cryomicrotome sections reveal the undisturbed anatomy of the epidural space to be less uniform and more

complex than previously reported. Further study of the structural details of spinal soft tissue anatomy may lead to improved techniques for epidural needle and catheter placement and to a better understanding of the distribution and action of drugs administered in the epidural space.

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