

# Topographical anatomy of the lumbar epidural region: an *in vivo* study using computerized axial tomography

G. R. Harrison

*Featherstone Department of Anaesthesia and Intensive Care, Queen Elizabeth Hospital, Edgbaston, Birmingham B15 2TH, UK*

The lumbar epidural region was studied using computerized tomography. This technique allows examination of the region *in vivo*. It confirmed that the spinal canal is oval in the upper lumbar region, becoming triangular lower down, and that the ligamenta flava form a posterior recess to the vertebral canal. Epidural fat is confined to this region between the ligamenta flava and the intervertebral foramina, and the dura mater lies apposed to the walls of the vertebral canal except where there is epidural fat. The absence of a posterior midline fold of dura mater was noted, and discussed in the light of other studies.

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The anatomy of the epidural space is important to anaesthetists who use it as a means of providing analgesia and anaesthesia through the neuraxis, although not a great deal of interest was shown until studies were performed to demonstrate the existence or otherwise of a median fold of dura mater to explain unilateral epidural sensory block.<sup>1,2</sup> Such studies and those using dissection or epiduroscopy invariably alter the natural state of the region, either by introducing resin, an epiduroscope or by mechanical destruction in the case of dissection.

With the advent of modern imaging techniques, cross-sectional images of the lumbar epidural space can be obtained without introducing artefacts. I have examined the anatomy of the epidural space qualitatively and quantitatively using computerized tomography scanning (CT).

## Methods

The serial CT scans of the lumbar spine of 15 patients, aged 35–70 yr, were examined. They were selected at random from scans performed for the diagnosis of back pain. The high resolution scans were made on a GE 8800 scanner, with 1.5-mm slices being taken at 3-, 5- or 10-mm intervals over the whole of the lumbar spine, with the patient in the supine position. From these scans it was possible to assess the following features: the shape of the vertebral canal; position and shape of the dural sac within the canal; position of fat within the epidural region; and organization of the ligamenta flava. Distances from the skin to the posterior border of the epidural region in the midline, from the posterior border of the epidural region to the dural sac and from the posterior longitudinal ligament to the

inferior vena cava were measured, in addition to the coronal and sagittal diameters of the vertebral canal, and the length and width of the ligamenta flava. The window width was maintained at 1000 Hounsfield units and the window centre at 145 Hounsfield units for all measurements, which were made to the nearest millimetre using the measurement facility available on the display monitor.

## Results

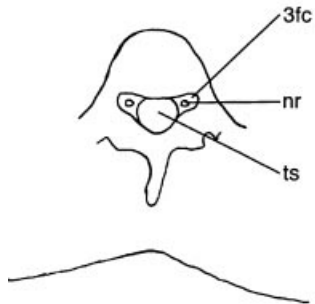
The vertebral canal was oval in the upper lumbar region (Fig. 1), tending to being triangular (Fig. 2) or trefoil (Fig. 3) in the lower lumbar region. The shape of the vertebral canal is determined by the position of soft tissues and bone. The main structures forming the posterior part of the vertebral canal are the vertebral arch and the ligamenta flava. These ligaments are two discrete bodies with a midline gap between them (Fig. 4), except in some cases where the inter-spinous ligament fills the gap and at the level of the lamina where they combine posteriorly (Fig. 5). The ligamenta flava, lying at an angle to the midline of approximately 30°, form a posterior recess to the vertebral canal which is filled with fat (Fig. 5). Fat is found normally only in this recess and in the intervertebral foramina, but it may be present in the anterolateral recesses which are present when the vertebral canal becomes triangular or trefoil (Fig. 3). The dura mater lies within the vertebral canal, apposed to the walls of the canal where they are bony (Fig. 1) and ligamentous (Fig. 5), and to the epidural fat in the areas where it lies in the recesses described above. A dorsal midline fold of dura mater was not observed in any of the scans.



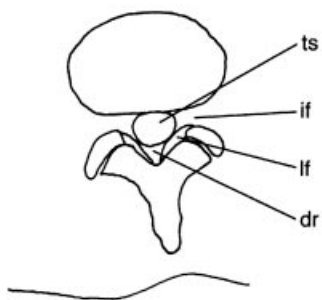
**Fig 1** Scan of the first lumbar vertebra demonstrating the ovoid shape of the vertebral canal. The contents of the thecal sac (ts) are seen as a uniformly grey area filling the vertebral canal with no gap between it and the laminae (l).



**Fig 2** Scan through the fifth lumbar vertebra demonstrating the triangular shape of the vertebral canal, with anterolateral recess (tvc). The zygapophyseal joint (zj) is shown and the iliac crest (ic).



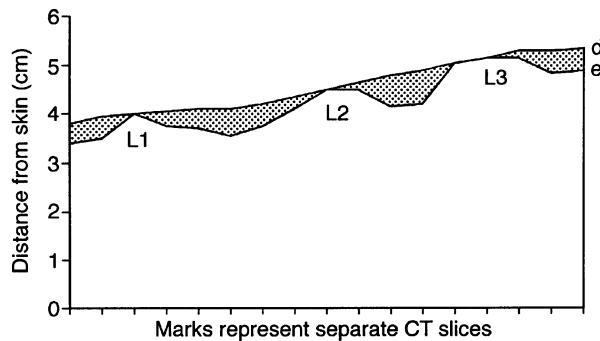
**Fig 3** Scan through fourth lumbar vertebra demonstrating the trefoil configuration of the vertebral canal (3fc). Because of contrast media in the thecal sac (ts), the sac appears whiter than in the other scans. The nerve roots (nr) are visible because of contrast within the lateral recesses which are fat filled.



**Fig 4** Scan through the L2-3 disc. The thecal sac (ts) is bounded by fat posteriorly in the dorsal recess (dr) and in the intervertebral foramina (if). Posterolaterally, the sac is in apposition to the ligamenta flava (lf) which are clearly demonstrated as two separate ligaments.



**Fig 5** Scan through the third lumbar vertebra demonstrating the conjunction of the ligamenta flava (lf) forming a dorsal recess (dr).



**Fig 6** Relationship between the dura mater (d) and the posterior border of the epidural space (e). The shaded areas represent the posterior recesses of the epidural region, and L1, L2 and L3 mark the position of the relevant vertebral arches.

**Table 1** Distances measured (mean (SD) centimetres)

Skin to epidural space	4.9 (1.0)
Vertebral canal	
Sagittal diameter	1.7 (0.3)
Coronal diameter	2.5 (0.4)
Vertebral canal to inferior vena cava	3.5 (0.4)
Ligamenta flava	
Length	1.6 (0.3)
Width	0.3 (0.1)

The measurements obtained are presented in Table 1, apart from the distance from the dura mater to the posterior border of the epidural region. This value varies along the length of the spinal canal depending on where the

measurement is made. It varies from the situation at the level of the vertebral arch where there is no space between the dura mater and the posterior border of the epidural region, to that at the level of the ligamenta flava where this distance is up to 8 mm. From serial measurements made in one subject, the values for the distance from the skin to the epidural region and from the epidural region to the dura mater were plotted against the position along the vertebral canal to give a diagram of the posterior border of the epidural region in the sagittal plane (Fig. 6). From this it can be seen that the distance from the skin to the epidural region gradually increases from L1 to L4, that the dura mater lies over the posterior wall of the epidural region and that the posterior recesses are apparent.

## Discussion

Other studies have described the anatomy of the epidural space from CT scans.<sup>3-5</sup> However, this study is unique in that, unlike other reports, it was performed without the introduction of contrast media into the epidural space which could cause distortion.

The shape of the lumbar vertebral canal was found to be oval in the upper lumbar region, becoming triangular or trefoil in the lower lumbar region, in agreement with Eisenstein.<sup>6</sup> The description of the ligamenta flava corresponds well with my previous study<sup>7</sup> and that of Hogan,<sup>8</sup> and confirms the presence of a midline gap between the ligaments, although this is not always a constant feature.



Fat in the epidural region is present normally only in the posterior recesses between the ligamenta flava, and in the intervertebral foramina. This is in contrast with descriptions of the epidural region as being filled with fat<sup>9</sup> but agrees with the more recent studies by Hogan,<sup>8</sup> and Reynolds and colleagues<sup>3</sup>. The absence of fat in the epidural region, except where described, means that the dura mater is generally applied to the wall of the vertebral canal. There is no space apparent between the vertebral canal and the dural sac, and this calls into question the implications of previous work<sup>1 2 4 5</sup> which attempted to quantify the distortion produced by injection of various compounds into the epidural region, and implied that there is a space apparent between the walls of the vertebral canal and the dura mater.

The midline fold of the dura mater (PMD), described by several authors,<sup>1 2 4 5</sup> was not noted in any of the scans reviewed in this study. In contrast, Savolaine and colleagues<sup>4</sup> recorded a PMD in all patients. If PMD is actually a fold of dura mater it could be asked if the resolution of the scanner is adequate to demonstrate its presence. However, from the references quoted above, this structure is quite large. The PMD described is probably the midline posterior fat pedicle being displaced from its normal anatomical position between the ligamenta flava by the injected contrast medium, a view supported by Morisot.<sup>10</sup> This pedicle of fat has been described as a potential barrier to the spread of fluid in the epidural space.<sup>8</sup>

The scans had a higher resolution than normal to allow for a more detailed examination of a specific area to be achieved. The process of 'target reconstruction' is not simply magnification or image enlargement, rather it is a process by which the scanner is able to produce an image made up from pixels of 0.25 mm, whereas the normal pixel size for a third generation scanner is nearer 1.5 mm.<sup>11</sup> In view of pixel size, measurements were made to the nearest millimetre. The window centre and width were chosen empirically to provide the best image of the structures being assessed. The nature of the disease of these patients (back pain) may provoke the argument that the findings are not necessarily typical for the normal population. However, experience over the years has indicated that if they have a lesion, most patients with back pain have problems with the anterior epidural region, and usually there are no problems associated with the posterior epidural region.

The measurements provided by this study have corroborated the findings of others. The values for the distance from the skin to the epidural region support those made clinically,<sup>12</sup> and also confirm the increase in distance from the skin to the epidural region from the first to the third lumbar interspace. The distance from the posterior point of the epidural region to the dura mater, when plotted, demonstrated a posterior recess between the dura mater and the ligamenta flava, and showed graphically how the epidural fat comes to occupy the gaps between the dura mater and the vertebral canal whereas at the level of the vertebral arch nothing separates the dura mater from the

posterior border of the vertebral canal. This agrees with the cryotome study of Hogan,<sup>8</sup> which comments that the epidural contents are found in metamerically segmented compartments rather than in a uniform layer, and that large areas of the dura mater are in contact with the spinal canal wall. This is described by Reynolds and colleagues<sup>3</sup> as a sawtooth shape to the epidural space.

The dimensions of the ligamenta flava are in accord with previous studies,<sup>7</sup> as are those of the spinal canal.<sup>13 14</sup> The distance from the vertebral canal to the inferior vena cava (IVC) was measured as this would assist in determining the hydrostatic pressure difference between the IVC and the veins of the epidural venous plexus. This value is somewhat less than that quoted by Shah<sup>15</sup> and may have implications in future physiological assessments of epidural space pressure.

The scans had to be performed in the supine position, which is not the normal position of patients during insertion of an epidural catheter. The above correlations with other studies suggest that this does not cause differences sufficient to invalidate the results. The effect of gravity on the dural sac may alter its length when in the erect position, but would not be expected to influence it when in the lateral position in comparison with the scan position. The dural sac is an elastic structure and can alter its length in a variety of conditions,<sup>16</sup> but the diameter is constrained by the surrounding structures of the spinal canal. This is constant under normal physiological conditions, and the cerebrospinal fluid pressure maintains the apposition between the dural sac and spinal canal. The structures remain apposed posteriorly as the connections between the dura and spinal canal are loose, but the anterior connections are much stronger and the dura is relatively adherent to the posterior longitudinal ligament.<sup>7</sup>

Magnetic resonance (MR) imaging can also demonstrate the anatomy of the human body. With MR it is possible to reconstruct the image in any plane, be it transverse, coronal, sagittal or oblique, and the results of Figure 6 could have been obtained as a complete scan, without questions of accuracy of measurement or positional artefact. However, while the MR scan can differentiate well between certain structures in relation to their content of fat and water, it is poor at demonstrating bone. There is no overall difference between CT and MR in the information obtained in the cross-sectional anatomy of the epidural region studied here.

In summary, this study corroborated the findings of Hogan taken from cryomicrotome studies of the epidural space, and demonstrated that radiological studies of the epidural region made without insertion of contrast media give images representative of normal anatomy. The quantitative aspects should help to increase the safety of inserting an epidural catheter, a procedure which is already associated with a very low level of morbidity.

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