STUDY OF THE ANATOMY OF THE EXTRADURAL REGION USING MAGNETIC RESONANCE IMAGING

J. L. WESTBROOK, S. A. RENOWDEN AND L. E. S. CARRIE

SUMMARY
We have studied magnetic resonance images of the lumbar spine of 39 subjects to examine the anatomy of the lumbar extradural region. The segmental nature of the posterior extradural region at each lumbar level may explain reports of easier cranial passage of extradural catheters introduced by the paramedian approach. This approach may thus provide a more reliable route for rapid introduction of an extradural catheter during the needle-through-needle, combined spinal–extradural technique. (Br. J. Anaesth. 1993; 71: 495-498)

KEY WORDS

Most anaesthetic texts describing the conduct of extradural anaesthesia stress the importance of a detailed knowledge of the anatomy of the region. Unfortunately, descriptions in standard anatomy or anaesthetic books may not provide the reader with a clear or accurate image of the anatomy or dimensions of this area, the most likely reason being the problems inherent in its study. The principal difficulty is that, in life, the extradural region exists largely as a "potential space" [1]—a term used by Bromage to reflect, not only the minimal contents of the extradural space but also its capacity to expand to accommodate very large volumes of injected fluid or air. Parkin and Harrison [2] have advocated use of the term "extradural region" rather than "extradural space" in order not to suggest a space of large resting volume.

Many different techniques have been used in the study of the anatomy of the extradural region, but they all have limitations and are subject to artefact. Cadaveric dissection [2] is subject to distortion because of postmortem autolysis and preservation with agents that alter tissue properties; furthermore, the loss of cerebrospinal fluid (CSF) pressure at death and possible increase in venous pressure result in changes in the relative volumes occupied by the dural sac and venous plexuses within the spinal canal. All techniques requiring the injection of fluid or air into the extradural region distort the anatomy; such methods have included resin injection studies [3], extradurography and computed tomography (CT) extradurography [4], extraduroscopy [5] and spinaloscopy [6]. More recently, a study using cryomicrotome sectioning of cadavers has provided some detailed information less distorted by artefact [7].

Magnetic resonance imaging (MRI) is the most rapidly advancing of the imaging specialties. Developments in computer technology have provided for greater image resolution, detailed tissue contrast without use of contrast media and images acquired in any plane. The physics of MRI has been reviewed [8].

The purpose of this study was to examine the anatomy and dimensions of the extradural region using MRI and to compare the information obtained with that from other investigative techniques.

PATIENTS AND METHODS
The anatomy of the lumbar extradural space was studied retrospectively using lumbar MRI scans of 39 patients. The examinations had been undertaken because of low back pain, but the images were reported as normal by a neuroradiologist. The patients comprised 22 men and 17 women, aged 18–64 yr (median 38 yr). All MRI examinations were performed with a GE Signa Advantage scanner operating at 1.5 T (tesla), with the patient supine. Using a surface coil and fast spin echo (FSE), T1-weighted (T1W) and T2-weighted (T2W) sagittal scans were obtained, followed by FSE axial T2W scans through the lower four lumbar discs.

Using computer software, direct measurements were taken from the stored, computerized images in multiple planes at the L2–3 level (fig. 1) to record the following data: distance from the skin to the extradural region; the angle of the lumbar spinous processes relative to the long axis of the spine; furthermore, the loss of cerebrospinal fluid (CSF) pressure at death and possible increase in venous pressure result in changes in the relative volumes occupied by the dural sac and venous plexuses within the spinal canal. All techniques requiring the injection of fluid or air into the extradural region distort the anatomy; such methods have included resin injection studies [3], extradurography and computed tomography (CT) extradurography [4], extraduroscopy [5] and spinaloscopy [6]. More recently, a study using cryomicrotome sectioning of cadavers has provided some detailed information less distorted by artefact [7].

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Using computer software, direct measurements were taken from the stored, computerized images in multiple planes at the L2–3 level (fig. 1) to record the following data: distance from the skin to the extradural region; the angle of the lumbar spinous processes relative to the long axis of the spine; distance between adjacent laminae; distance between the anterior surface of the ligamentum flavum and the dura at the cranial end of the lumbar segment, at the mid-point of the ligamentum flavum and at the
caudal end of the lumbar segment. These measurements were taken in a straight line from a "skin puncture" site between two adjacent spinous processes, as this would be the route followed by an extradural needle.

![Diagram showing anatomy and planes of measurement.](image)

**Fig. 1.** Diagram showing anatomy and planes of measurement.

**Fig. 2.** T1W sagittal mid-line MR image showing vertebrae T11-S2, the intervening discs (d) and the overlying posterior longitudinal ligament (pll). The dural sac lies within the spinal canal. The CSF is of low signal (dark) and the conus (c), of higher signal, is located at L1. The nerve roots of the cauda equina (ce) are demonstrated to lie posteriorly. Posterior to the dural sac, extradural fat (f), which is of high signal (white) on T1W images, is demonstrated at levels T11-12 to L3-4, giving a "saw toothed" pattern to the extradural region. The fat is divided into segments by the interposing laminae. The extradural space is deeper at the cranial end than at the caudal end.

**Fig. 3.** T2W axial MR image at L3-4, between the two laminae. On T2W sequences CSF is of high signal (white) and the nerve roots of the cauda equina (ce) are well demonstrated within the dural sac. Fat is of intermediate signal; posterior to the dura is a triangle of extradural fat (f), bordered posterolaterally by the ligamentum flavum (lf). Laterally the confines of the extradural space are less defined.

**Fig. 4.** T2W axial image at the level of the L3 lamina. The dural sac is located adjacent to the anterior surface of the lamina (la). There is no intervening extradural fat. sp = Spinous process of L3; ps = psoas muscle.

**RESULTS**

Representative MRI images are illustrated in figures 2-4. Measurements obtained at the L2-3 level are documented in table I. There was no significant difference between the results of male and female subjects.

**DISCUSSION**

The extradural region is contained entirely within the spinal canal and itself contains the spinal extension of the dural sac (terminating at S1-2 in the

**Table I. Measurements taken from MR images at the L2-3 level (mean (SD) [range])**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean (SD) [Range]</th>
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<tbody>
<tr>
<td>Skin-ligamentum flavum</td>
<td>49.7 (11.75) [30-85] mm</td>
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<tr>
<td>Ligamentum flavum-dura mater</td>
<td></td>
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<tr>
<td>Cranial</td>
<td>5.97 (1.35) [4-9] mm</td>
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<tr>
<td>Mid-point</td>
<td>6.15 (1.31) [4-9] mm</td>
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<tr>
<td>Caudal</td>
<td>3.95 (1.1) [2-7] mm</td>
</tr>
<tr>
<td>Interlaminar distance</td>
<td>21.44 (2.79) [15-27] mm</td>
</tr>
<tr>
<td>Angle of spinous process to long axis</td>
<td>70.7 (5.1) [63-83]°</td>
</tr>
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adult), nerve bundles, blood vessels, lymphatics and fat. Its superior margin is at the foramen magnum where the peristeam and dura fuse. The inferior margin of the extradural region is at the sacrococcygeal membrane. Anteriorly, the region is bounded by the posterior surface of the posterior longitudinal ligament overlying the vertebral bodies and intervertebral discs. The posterior margin of the extradural region comprises alternating vertebral laminae and the ligamentum flavum on each side of the midline. Laterally, the borders of the “space” are less well defined—the bony pedicles form part of the boundary and between them the intervertebral foramina; however, the exact point at which the extradural region ends and the paravertebral region begins within the foramina is not clearly defined.

The ligamentum flavum has been studied extensively. At each spinal level there are two ligma- menta, one on each side of the midline, meeting at an angle of 90° or less [7, 9]. Most reports show that the ligamenta do not always meet in the mid-line, the gap being filled by the anterior margin of the interspinous ligament [2, 7, 9]. Cadaveric studies have shown the ligamentum flavum to be 2–5 mm thick [2, 9], although some authors have claimed the ligament to be up to 10 mm thick in obstetric patients [10, 11].

The feature of the extradural region that is very clearly demonstrated on mid-line sagittal sections on MRI is the segmented shape of the posterior extradural space. This has been shown previously using plain lumbar x-rays and CT after injection of iodized oil into the extradural space of 19 subjects [4]. The authors of that study described the shape of the extradural space in this plane as “saw-toothed”. They recorded the depth of the extradural space at the cephalic end as 1.6 mm ± 0.32 mm and that at the caudal end 8.3 mm ± 1.95 mm (at the level of T12). This differs from the data obtained in the present study, in which the caudal end has been shown to be the narrower part of the space (3.95 mm) compared with the cranial end (5.97 mm). The former study required injection of contrast, which may have caused distortion; furthermore, the lower thoracic region was studied and compensation was not made for the magnification inherent in plain film images. These data have been quoted as a reason for attempting to enter the extradural space at its caudal end [12]. We agree with this recommendation, but for the different reason given below.

The segmentation of the posterior extradural region observed by us has been described previously in dissection studies. Parkin and Harrison [2] studied 12 embalmed cadavers, whilst Hogan [7] studied 38 cadavers using cryomicrotome techniques. The latter work is in agreement with the present study showing the segmental extradural region to be narrower at the caudal end.

It may be seen from the MR images in this study that, at each segmental level, the extradural region narrows abruptly at its cranial end as the lamina becomes adjacent to the dura. Should the Tuohy needle enter the space in this superior part, attempts introducing the catheter may meet with almost immediate obstruction as it strikes the inferior surface of the laminae. This may be compared with a needle that enters the space at the caudal end and has unobstructed passage for the catheter of 15–27 mm. With the “blind” nature of the mid-line approach to the extradural space, the operator has little control over which portion of the ligamentum flavum is punctured. This study has shown that the angle of the spinous processes between which the mid-line needle must pass ranges from 63° to 83°. With the mid-line approach, if the spines are angled at 80°, the needle is likely to puncture the ligamentum flavum at its cephalic end. If the spines are at 60°, the needle is more likely to puncture the ligamentum flavum at the caudal end. Any such differences would be exaggerated, the greater the distance between the skin and the ligamentum flavum. However, the bony landmark afforded by the paramedian approach enables the operator to “walk off” the inferior lamina and so always enter the extradural space at the caudal end. This may explain reports showing that the passage of paramedian catheters is less commonly obstructed and that they more commonly follow a straight cranial path [5, 13–15].

Although entering the extradural space at its caudal and therefore shallower extent could be associated with a greater risk of dural puncture, the oblique passage of the extradural needle during the paramedian technique presents the dura at the rounded aspect of the Huber tip, thus making dural puncture unlikely. In addition, this angle of approach results in a catheter emerging from the needle in a plane more parallel to the dura and so less likely to cause tenting. It has been shown by Hardy [16] that a catheter cannot be pushed through intact dura, although it has been suggested that the dura may be punctured if already damaged by the Tuohy needle. Blomberg's extraduroscope study [5] of 14 cadavers confirms the above description, with all 14 paramedian catheters having a free cranial passage whilst all 14 mid-line catheters caused tenting of the dura and followed an unpredictable course.

A further controversy in the anatomy of this region is the possible presence of a dural fold extending posteriorly to the ligamentum flavum in the mid-line. This has been termed the plica mediana dorsalis [17] and should not be confused with the fibrous bands extending posteriorly in the mid-line between the dura and the ligamentum flavum. Such bands may be strong enough to divert extradural catheters [18]. One report using CT extradurography in 40 subjects described the plica mediana dorsalis as being present in 38; however, the authors were using the term to describe the fibrous bands and not true folds of dura [19]. As with other studies that did not involve the injection of fluid into the extradural region [2, 7] this study showed no evidence of a true plica mediana dorsalis. It would seem likely that previous descriptions have been the result of partial collapse of the dural sac by injected contrast or polyester resin [20] or on opening the extradural space at surgery. Under these circumstances, the fibrous bands support the midportion of the dura, giving the impression of a fold [21].
Advantages of the paramedian approach to the extradural region have been argued by a number of authorities [5, 22, 23], yet the mid-line approach appears to remain that practised most commonly by anaesthetists. A recent survey of U.K. obstetric units showed that 85% of anaesthetists preferred the mid-line approach, whilst 2% only used the paramedian route [24]. Some have avoided the paramedian approach on the grounds that it is more painful. This observation was made in a comparative study with the mid-line approach [25] using the same concentration and volume of local anaesthetic for both techniques. In fact, the soft tissues traversed with the paramedian route allow for easy injection of larger volumes of local anaesthetic which should render the method virtually painless.

The images and dimensions obtained in this study lend further support to the use of the paramedian route for extradural anaesthesia. The clear bony landmarks afford the practitioner a known level for entering the extradural space, relative to the lamina, that is most likely to afford unobstructed passage of the extradural catheter. The increasing popularity of the combined spinal–extradural technique for regional anaesthesia in obstetrics may make this information more important. The needle-through-needle technique requires the ease passage of the extradural catheter after the injection of the subarachnoid local anaesthetic; this may be achieved more reliably by the paramedian route.

REFERENCES