Magnetic resonance imaging of the extradural space of the thoracic spine

Y. HIRABAYASHI, K. SAITO, H. FUKUDA, T. IGARASHI, R. SHIMIZU AND N. SEO

Summary
To clarify the anatomy of the extradural space of the thoracic spine, we have compared magnetic resonance (MR) images of the thoracic spine with those of the lumbar spine. In 20 healthy volunteers, T2-weighted axial MR images were obtained at the levels of the C7–T1, T7–8, T11–12 and L2–3 vertebrae. The posterior extradural space seen in the slice through the intervertebral disc varied in shape and size depending on the vertebral level, and the shape of the space converted from triangular to crescent-shaped on moving from the lumbar to the thoracic spine. In particular, the posterior extradural space was almost absent at the C7–T1 level, indicating that the posterior extradural fat was rudimentary or non-existent at the thoracocervical level. At this level, the dura mater seemed to be in direct contact with the ligamentum flavum. Segmentation of the posterior extradural space was commonly observed at the L2–3 and T11–12 levels; however, incomplete segmentation of the posterior extradural space was often present at the T7–8 level. (Br. J. Anaesth. 1997; 79: 563–566).

Key words
Anatomy, extradural space. Measurement techniques, magnetic resonance imaging.

Understanding of the anatomy of the extradural space is the key to successful introduction of extradural catheters and medicines. Because extradural anaesthesia and analgesia is most frequently performed at the lumbar vertebral level, the anatomical study of the extradural space has been studied extensively at this level.1–3 With respect to other vertebral levels, including the thoracic and cervical levels, however, few studies have been conducted.4 The anatomical characteristics of the spine are significantly different between the thoracic and lumbar spine, and thus the anatomy of the extradural space may differ according to the vertebral level. Magnetic resonance (MR) imaging provides detailed information on the anatomy of the extradural space in living subjects.5 To understand the anatomy of the extradural space at the thoracic vertebral level, we have compared MR images of the thoracic spine with those of the lumbar spine.

Subjects and methods
The Institutional Review Board approved our study, and informed consent was obtained from all subjects. We studied 20 healthy Japanese volunteers (14 men), aged 21–41 yr (median 28 yr). Mean weight, height and body mass index were 64 (range 47–85) kg, 167 (153–182) cm and 23 (19–28) kg m−2, respectively. Subjects with lumbago or previous spinal surgery were excluded. MR imaging examinations were performed with the subject in the supine position. At the levels of the C7–T1, T7–8, T11–12 and L2–3 vertebrae, T2-weighted axial MR images were obtained using an MR imaging system (VISART/Progress, Toshiba Corporation, Tokyo, Japan) operating at 1.5 T. Technical specifications included a repetition time of 4000–5500 ms, echo time of 100 ms, slice thickness of 4 mm, number of slices 9–11 and a field of view of 20 cm. Measurements taken from the MR images included the area of the dural sac, sagittal and transverse diameters of the dural sac, anteroposterior dimension of the fat-filled posterior extradural space, and distance from the skin to the posterior extradural space. The area was measured using a digital planimeter (KP-90N, Uchida Yoko Ltd, Tokyo, Japan).

Data were analysed using ANOVA for differences among the four levels of the spine. If significant differences were observed, the Bonferroni test was used for post hoc analysis. Data for men and women were compared using the unpaired t test. P<0.05 was considered statistically significant.

Results
The axial slice through the intervertebral disc showed that the posterior extradural space was enclosed by the ligamentum flavum, articular capsule and the dura. The fat in the posterior extradural space, having a high signal and being uniform (white), appeared as a triangle, typically at...
the lumbar spine (fig. 1A). The fat-filled posterior extradural space varied in shape and size depending on the vertebral level. The shape of the space converted from triangular (fig. 1C) to crescent-shaped (fig. 1B) on moving from the lumbar to the thoracic spine. The anteroposterior dimension of the fat-filled posterior extradural space was shorter at the thoracic levels than at the lumbar level ($P < 0.001$) (table 1). The fat-filled posterior extradural space appeared as a thin crescent at the T7–8 level in all subjects (fig. 1A); however, at C7–T1, the space was almost absent (fig. 1A), indicating that the posterior extradural fat was rudimentary or non-existent at the thoracocervical level.

In contrast with the axial slice through the intervertebral disc, as a rule no posterior extradural fat was evident in the axial slice through the pedicles (fig. 2) and lamina (fig. 3). This indicated that the
Table 1  Measurements taken from MR images at the C7–T1, T7–8, T11–12 and L2–3 levels (mean (sd) [range]). **P<0.01, ***P<0.001 (Bonferroni test) vs L2–3

<table>
<thead>
<tr>
<th></th>
<th>C7–T1</th>
<th>T7–8</th>
<th>T11–12</th>
<th>L2–3</th>
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<tbody>
<tr>
<td>Area of the dural sac (cm²)</td>
<td>1.7 (0.3) [1.2–2.3]</td>
<td>1.6 (0.3) [1.2–2.2]</td>
<td>1.8 (0.4) [1.2–2.4]</td>
<td>1.8 (0.3) [1.3–2.4]</td>
</tr>
<tr>
<td>Transverse diameter of the dural sac (mm)</td>
<td>17.5 (1.7) [14–21]</td>
<td>16.6 (1.8) [13–19]***</td>
<td>16.7 (2.3) [13–21]**</td>
<td>18.4 (1.9) [16–22]</td>
</tr>
<tr>
<td>Sagittal diameter of the dural sac (mm)</td>
<td>12.3 (1.1) [10–15]</td>
<td>13.4 (1.2) [11–16]</td>
<td>13.8 (1.8) [11–17]**</td>
<td>12.5 (1.2) [11–15]</td>
</tr>
<tr>
<td>Anteroposterior dimension of the posterior extradural space (mm)</td>
<td>0.4 (0.9) [0–3]***</td>
<td>2.6 (1.3) [0–5]***</td>
<td>4.1 (1.1) [3–6]***</td>
<td>7.1 (1.3) [4–9]</td>
</tr>
<tr>
<td>Distance from the skin to the posterior extradural space (mm)</td>
<td>55.4 (8.2) [41–73]***</td>
<td>36.7 (4.3) [30–44]</td>
<td>35.9 (5.9) [26–46]</td>
<td>38.2 (6.3) [27–48]</td>
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</table>

Table 2  Comparison between men and women for measurements taken from MR images at the C7–T1, T7–8, T11–12 and L2–3 levels (mean (sd) [range]). *P<0.05, **P<0.01 (unpaired t test) vs women

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>C7–T1</th>
<th>T7–8</th>
<th>T11–12</th>
<th>L2–3</th>
</tr>
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<tbody>
<tr>
<td>Area of the dural sac (cm²)</td>
<td>Men</td>
<td>1.7 (0.3) [1.2–2.3]</td>
<td>1.7 (0.3) [1.2–2.2]</td>
<td>1.8 (0.4) [1.2–2.3]</td>
<td>1.8 (0.3) [1.3–2.5]</td>
</tr>
<tr>
<td>Transverse diameter of the dural sac (mm)</td>
<td>Women</td>
<td>1.5 (0.1) [1.4–1.7]</td>
<td>1.6 (0.2) [1.4–1.9]</td>
<td>1.9 (0.6) [1.2–2.4]</td>
<td>1.8 (0.4) [1.4–2.3]</td>
</tr>
<tr>
<td>Sagittal diameter of the dural sac (mm)</td>
<td>Men</td>
<td>18.1 (1.6) [14–21]**</td>
<td>15.8 (2.1) [13–19]</td>
<td>16.4 (2.1) [13–19]</td>
<td>18.4 (1.7) [16–22]</td>
</tr>
<tr>
<td>Anteroposterior dimension of the posterior extradural space (mm)</td>
<td>Women</td>
<td>16.0 (0.8) [15–17]</td>
<td>15.3 (0.8) [14–17]</td>
<td>17.1 (2.9) [13–21]</td>
<td>18.4 (2.3) [16–22]</td>
</tr>
<tr>
<td>Distance from the skin to the posterior extradural space (mm)</td>
<td>Men</td>
<td>57.3 (7.8) [41–73]</td>
<td>37.0 (4.1) [30–44]</td>
<td>37.6 (4.5) [29–46]*</td>
<td>40.0 (5.4) [33–48]*</td>
</tr>
<tr>
<td>Distance from the skin to the posterior extradural space (mm)</td>
<td>Women</td>
<td>50.9 (7.8) [41–62]</td>
<td>35.8 (4.9) [31–44]</td>
<td>31.9 (7.4) [26–46]</td>
<td>34.1 (6.7) [27–42]</td>
</tr>
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posterior extradural compartment was discontinuous, separated by areas of contact of the dura with the rostral lamina. At the level of the rostral lamina, no posterior extradural fat was present at T11–12 (fig. 2c, 3c) and L2–3 (fig. 2b, 3b), or at C7–T1 (fig. 2a, 3a) in any subject. There were no differences between men and women for measurements at the other three levels of the spine. The distance from the skin to the extradural space was greater in men than in women in the low thoracic and lumbar regions (P<0.05).

Discussion

Increasing evidence indicates that the extradural space is divided into posterior, anterior and lateral compartments by areas where bone and ligament are in contact with dura, although traditional teaching describes this space as a circumferential structure. These three compartments distribute segmentally around the dural sac. The posterior extradural space is the space into which the needle and catheter enters during extradural anaesthesia, and hence understanding of the anatomy of the posterior extradural space is the key to successful block. The posterior extradural space contains chiefly fat which appears as a high signal on T2-weighted MR images. The fat within this space may follow the margin of the posterior extradural space. The findings of this study showed that the posterior extradural fat significantly varied in shape and size depending on the vertebral level. The shape of the posterior extradural fat changed from triangular to crescent-shaped on moving from the lumbar to the thoracic spine. At the thoracocervical junction, posterior extradural fat was almost absent. These findings may suggest that the effective capacity of the posterior extradural space reduces on passing from the lumbar to the thoracic level. The progressively diminishing posterior extradural fat in levels cephalad from the lumbar spine may, in part, explain the smaller anaesthetic dose requirements at the thoracic and cervical regions than in the lumbar region.

In the low-thoracic and lumbar vertebral level, the posterior extradural fat was present in the axial slice through the intervertebral disc but not in the axial slices through the pedicles and lamina, which may suggest that the posterior extradural compartment is discontinuous, separated by areas of contact of the dura with the rostral lamina. The mid-thoracic spine, however, often showed a continuous layer of posterior extradural fat which extended between the dura and lamina even at the level of the rostral lamina. This indicated that the fat in the posterior extradural space at the mid-thoracic spine extended from one compartment to the next between the dura and lamina. Significant differences between men and women were noted only at the C7–T1 level for measurements of the dural sac (table 2). There were no differences between men and women for measurements at the other three levels of the spine. The distance from the skin to the extradural space was greater in men than in women in the thoracic and lumbar regions (P<0.05).
at the mid- and upper thoracic levels. Incomplete segmentation of the posterior extradural space at thoracic levels may, in part, explain the fact that catheters are easily inserted for a far longer distance without kinking in the thoracic than in the lumbar region.10

Textbooks describe the anteroposterior dimension of the posterior extradural space in the lumbar region as 5–6 mm11 or 4–6 mm.12 Nickallis and Kokri reported that the mean value of the dimension in the lumbar region was 6.6 (SD 1.9) mm.13 Bevacqua, Haars and Brand published a value of 6.9 (4) mm.9 Our study showed that the value of the anteroposterior dimension of the posterior extradural space at the L2–3 interspace was 7.1 (1.3) mm, which does not differ significantly from those published previously. With respect to the thoracic region, however, few studies have been conducted on the size of the extradural space.12 The values reported in our study are, to our knowledge, the first measurements by MR imaging. In a recent detailed study of cryomicrotome section of the thoracic spine, the anteroposterior dimension of the posterior extradural space was not measured.6

The diminished anteroposterior dimension of the posterior extradural space in the upper and mid-thoracic spine suggests an increased incidence of unintentional dural perforation during extradural puncture. However, Giebler, Scherer and Peters reported that unintentional dural perforation was observed significantly less in the mid- and upper thoracic regions in 4185 patients receiving thoracic extradural catheterization.14 Tanaka and colleagues also reported significantly less unintentional dural perforations in the cranial vertebral regions compared with the lower thoracic and lumbar regions.15 Thoracic extradural procedures are usually attempted by clinicians with considerably more experience whereas new trainees usually start with patients requiring the lumbar approach, and thus there may well be a learning curve. In addition, in the mid-thoracic region, the laminae overlap and angulation of the spinous processes is steep. Consequently, cephalad angulation of the needle is required during insertion. This cephalad angulation produces a longer oblique course across the extradural space and may compensate for the diminished anteroposterior dimension of the posterior extradural space.6 This obligatory angle also makes the blunt back surface of the Tuohy needle face the dura.

This study was performed in subjects of Japanese origin. All of our volunteers were of relatively small stature and weight compared with European or North American subjects, and hence the results of this study can be applied directly only to subjects of the same race and within the same age, stature and weight range of those in this study. In addition, the number of volunteers examined in this study was so small that definitive conclusions on the differences between men and women cannot be reached.

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References