A study of the anatomy of the caudal space using magnetic resonance imaging

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Summary

We have studied, in 37 adult patients, the anatomy of the sacral extradural (caudal) space using magnetic resonance imaging. The sacrococcygeal membrane (SCM) could not be detected in 10.8% of patients. The maximum depth of the caudal space adjacent to the SCM was beneath the upper third of the SCM in more than 90% of patients (mean depth 4.6 mm; range 1.0–8.0 mm). The shortest linear distance from the dura to the upper limit of the SCM varied considerably (60.5 mm; 34–80 mm) as did the volume of the caudal space excluding the foraminae and dural sac (14.4 cm³; 9.5–26.6 cm³). The dimensions of the caudal space and their variability have implications for clinical practice and a knowledge of these dimensions may increase both the reliability and safety of caudal techniques in adult patients. (Br. J. Anaesth. 1997; 78: 391–395).

Key words

Anatomy, extradural space. Anaesthetic techniques, extradural. Measurement techniques, magnetic resonance imaging.

The caudal approach to the extradural space (caudal block) is used for intraoperative and postoperative analgesia for a variety of operations and for the management of chronic pain. The sacral hiatus marks the termination of the sacral canal and results from failure of fusion of the laminae of the fifth sacral vertebra. To perform a caudal block, the sacral hiatus must first be located and a needle passed through the sacrococcygeal membrane (SCM). This can be difficult or impossible at times because of wide anatomical variation in this region. A detailed understanding of the anatomy of the caudal region of the extradural space is therefore desirable for clinicians using this technique.

Current anatomical knowledge of this region is based largely on post-mortem studies from more than 50 yr ago. These were performed after a revival of interest in continuous caudal analgesia in obstetric practice.¹ In the same decade, the “recent” and skeletonized sacral anatomy of cadavers was studied² and the significance of variations in sacral anatomy for the use of caudal analgesia was discussed.³ However, cadaveric dissection is subject to distortion and measurements may alter after skeletonization of the cadaver.⁴ Furthermore, there have been anatomical changes in populations over the past 50 yr.

Recently, other anatomical areas such as the lumbar extradural region have been studied in life using magnetic resonance (MR) imaging.⁵ The purpose of our study was to examine the normal anatomy of the sacral extradural (caudal) space in adults using MR imaging.

Patients and methods

The study was carried out in the MR imaging suite at University Hospital, Nottingham. After a pilot study of 15 patients for familiarization and confirmation of the reproducibility of measurements, the anatomy of the caudal space relevant to the performance of caudal block was studied prospectively using MR images of 37 adult patients presenting for primary investigation of back pain. MR imaging was part of their routine investigation and no patient had evidence of congenital abnormalities such as spina bifida or a history of spinal surgery. Patient height, weight and sex were recorded. MR imaging was performed with a Siemens Vision scanner operating at 1.5 T (tesla) with the patient supine. A phased array spine coil was used. The relevant anatomy was demonstrated most clearly using T2 sagittal plane images and consecutive T2 sagittal images of 0.44 cm thickness of the sacrum from the upper margin of S1 to the caudad limit of the sacral hiatus were therefore used (fig. 1). Using the Siemens computer software, measurements were made by two of the authors (I. M. C. and B. P. B.) using stored images for each patient on two separate occasions. If there was a discrepancy between measurements, a third measurement was made and the mean value recorded.

The length (fig. 2) and thickness (fig. 3) of the SCM (if present) were measured on the images giving the largest measurement. Only that part of the SCM through which the sacral canal could be entered with a needle, that is the length of the SCM with clearly visible underlying caudal space, was
used for these measurements. The location of the upper limit of the SCM (corresponding to the apex of the sacral hiatus) in relation to the adjacent vertebral body was recorded. For example, “4.2” indicated that the upper limit of the SCM was adjacent to a position 4.2 vertebral bodies below the upper margin of the body of SI (fig. 2). The maximum depth (AP diameter, fig. 3) of the caudal space at an angle of 90° to the SCM and its location in relation to the SCM (upper or middle third of the SCM) were also recorded. The best fit angle for needle insertion into the caudal space via the upper third of the SCM was determined (fig. 4). This position was described by measuring the angle of caudal depression required from a line drawn at 90° to the SCM. The location of the lowest limit of the dural sac in relation to the adjacent vertebral body (as above) and the shortest linear distance from the dura to the upper limit of the SCM were recorded (fig. 2). The volume of the sacral canal excluding the foraminae and the dural sac was estimated by obtaining the product of the sum of the areas of the sacral canal from each T2 sagittal plane image and 0.44 (thickness of each consecutive T2 sagittal image).

Data were analysed where appropriate using Student’s t test and regression analysis. A probability of 0.05 or less was considered statistically significant.

**Results**

We studied 23 females and 14 males (table 1). In one patient, height and weight were not recorded. In two patients the volume of the sacral canal could not be recorded because of poor reproducibility of results. Data from these patients were excluded from appropriate analyses. There were significant differences between the heights and weights of females

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**Figure 1** T2 sagittal image of the sacrum and caudal space.

**Figure 2** Diagram of the sacrum and caudal space (using fig. 1 as a template) showing the shortest linear distance from the dura to the upper limit of the sacrococcygeal membrane (a), the length of the sacrococcygeal membrane (b) and the vertebral level of the caudal limit of the dura (“2.0”, c).

**Figure 3** Diagram of the sacrum and caudal space (using fig. 1 as a template) showing the maximum depth of the caudal space at 90° and adjacent to the sacrococcygeal membrane (“AP diameter”, a) and the maximum width of the sacrococcygeal membrane (b).

**Figure 4** Diagram of the best fit angle for needle insertion into the caudal space (X° = angle of caudal depression of the needle from position 1 to position 2).
and males ($P=0.001$ and $P<0.001$, respectively). Table 2 gives the measurements of the SCM, sacral canal and position of the lower limit of the dural sac. Data were comparable for females and males except that the SCM was significantly thicker in females ($P=0.005$) and the volume of the sacral canal was significantly greater in males ($16.5$ vs $13.2$ cm$^3$) ($P=0.019$). The relationships between sacral canal volume and height and sacral canal volume and weight are given by the regression equations: $y = -17.7 + 0.19x$ ($r^2=0.27$, $P=0.002$) and $y = 5.76 + 0.12x$ ($r^2=0.33$, $P<0.001$), respectively. There was no relationship between age and sacral canal volume ($y=17.1 - 0.06x$, $r^2=0.07$, $P=0.142$).

### Discussion

Successful performance of a caudal block requires identification of the sacral hiatus, passage of a needle through the SCM and placement of the needle (or cannula) along the axis of the sacral canal without entering the dural sac or other structures. This may be technically difficult in adult patients. A detailed knowledge of the anatomy, dimensions and variations of the sacral region are therefore desirable to increase the reliability and safety of using this technique. This knowledge is based mainly on the results of post-mortem studies performed more than 50 yr ago. We were particularly interested to compare our findings with this previous work. Although the patients included in our study presented for investigation of back pain, most of their symptoms originated from the lumbar region of the spine and none had undergone previous spinal surgery or had evidence of a congenital abnormality. We therefore assumed that the anatomy of their sacral region would be representative of the general population.

In 33 patients the SCM was identified easily and measured. However, we were unable to identify a sacral hiatus and SCM on the MR scans in four (10.8%) of our patients. Although we cannot be certain of its absence without axial imaging, in most patients this would represent a clinically insurmountable obstacle when performing a caudal block. Although Trotter and Lanier found obliteration of the hiatus in some of the skeletons in their study, the incidence was not recorded.$^5$

Trotter and Lanier$^5$ located the apex of the hiatus most commonly at the level of the lower third of the body of S4, although this varied greatly. We found the median and mode of the upper limit of the SCM to be at the level of the upper third of the body of S5, although there was also wide variation across two vertebral bodies. It would have been desirable to relate the site of the SCM to a palpable bony landmark such as the tip of the coccyx. However, the tip of the coccyx was not demonstrated clearly in many scans for technical reasons. Identification of other useful and palpable landmarks was also difficult as MR imaging was performed only in the sagittal plane. Our initial evaluation of axial imaging suggested that it added little to the information gained from the sagittal sections.

The mean length of the SCM in our study was
22.6 mm. This measurement was similar to the mean length of 26.3 mm obtained from a study of the “recent” anatomy of approximately 50 cadavers.\(^6\) However, the upper ranges for the bony length of the sacral hiatus for males and females (60 and 65 mm, respectively), as measured by Trotter and Lanier in the sacra of 518 white Americans\(^5\), were larger than for our males and females (31 and 36 mm, respectively). This may be related to our smaller sample size, measurement errors, population differences and almost certainly differences between living and post-mortem tissues.

The mean maximum AP diameter of the caudal space adjacent to the SCM for all of our patients was 4.6 mm. Trotter and Lanier found the mean maximum AP diameter to be 4.6 (SD 1.7; range 0–10) mm and 4.9 (1.5; 0–12) mm in white females and males, respectively.\(^5\) These measurements were similar to our results, although we measured the AP diameter at an angle of 90° to the SCM. This small dimension may contribute to the anatomical difficulties encountered during caudal techniques. Also, Trotter and Lanier found that in 5% of subjects the AP diameter of the canal at the apex of the hiatus was <2 mm. We found only one patient with a diameter of less than 2 mm. Our female patients demonstrated a trend towards larger AP canal diameters (\(P = 0.078\)). This latter observation may suggest that caudal techniques might be performed with less difficulty in female patients, although any differences are probably not clinically relevant. As the maximum canal diameter was found adjacent to the upper third of the SCM in most of our patients (95.5%), passage of a needle near the apex of the SCM might be expected to reduce difficulty in clinical practice.

A common technique for performing a caudal block is to insert the needle at an angle of 90° to the SCM until the ligament is penetrated, followed by depression of the needle until it is estimated that the shaft of the needle is in the plane of the sacral canal and then advancement along the canal.\(^6\) Given the wide variation in sacral anatomy, it is understandably easy to misplace the needle in adults. Our findings suggest that successful needle placement is more likely if the needle is inserted at 90° to the SCM and then depressed in a caudal direction through an angle of approximately 55–60°. However, the variation in this angle must be taken into account.

Early anatomical studies suggested that the volume of the sacral canal (including the sacral foraminae) in adults was slightly more than 30 (range 12–65) ml.\(^7\) However, this is the volume of dry bones and in life the canal is filled with the dural sac and its contents, nerves, blood vessels, fat and connective tissue. We estimated the mean volume of the sacral canal to be 14.4 (range 9.5–26.6) cm\(^3\), a much smaller volume than that reported previously. This could be explained partly by our measurement not including the volume of the dural contents or the volume of the sacral foraminae. Relating our measurement of canal volume to clinical practice is difficult. However, when making clinical decisions as to the injectate volume necessary for particular caudal techniques, it should be noted that previous radio-opaque dye injection studies have demonstrated variable leakage from the canal through the sacral foraminae.\(^8\) Furthermore, a relationship between age, height and the level of anaesthesia achieved with caudal extradural block has not been found\(^9\) although this has been reported after lumbar extradural block.\(^10\) Our study did, however, demonstrate some relationship between height and volume of the canal and weight and volume of the canal, although there was no relationship between age and volume.

Previous cadaver work has also shown wide variation in the position of the inferior extremity of the dura with a “mean” position adjacent to the middle third of the body of S2.\(^2\) In our study, the median position was also at the middle third of S2.

We found the mean shortest distance from the dura to the upper limit of the SCM to be longer than previous post-mortem findings, although the ranges were similar (60.5 mm, range 34–80 mm vs 47.4 mm, range 19–75 mm).\(^2\) The lower dimensions of these ranges are most relevant to clinical practice as the length of the needle performing the caudal block must be chosen carefully so as to avoid puncturing the dura. A 21-gauge, 40-mm “green” needle is often used to perform a caudal block. If this needle were inserted fully into the caudal space, there would be some patients in whom dural puncture might occur. Even a 23-gauge “blue” needle with a length of 25 mm should be used with caution.

In summary, we suggest that to increase the chances of performing a successful caudal block with minimal risk of dural puncture, the needle or cannula should enter the SCM in its upper third at 90° followed by caudal depression through an angle of 55–60° and advancement along the canal no more than is necessary (remembering that the shortest distance to the dural sac ranges from 34 mm in our study and 19 mm in a previous study). An absent hiatus and SCM should be considered if the block proves difficult or impossible to perform.

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**References**

