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Volumes of the spinal canal and caudal space in children zero to three years of age assessed by magnetic resonance imaging: implications for volume dosage of caudal blockade

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Abstract

Background. The primary aim of this study was to objectively assess the different spinal and caudal volumes that are of interest for caudal block volume dosing.

Methods. Three directly assessed (volume of spinal canal/caudal space, volume of the dural sac and volume of spinal cord) and two derived volumes (volume of the epidural space and cerebrospinal fluid volume) were determined from magnetic resonance images (MRI) in 20 children (zero - three yr of age). The assessed volumes were correlated to age, height and weight. Furthermore, the volumes of the epidural space from caudal canal to three different clinically relevant target levels (L 1, Th 10 and Th 6) and the epidural volume of each individual spinal segment at the caudal, lumbar and thoracic levels were calculated.

Results. All volumes correlated in a linear manner to length and weight (R^2 0.614 – 0.867) whereas a curvilinear correlation was associated with best curve fit for age (R^2 0.696 – 0.883). The median volumes of the epidural space from caudal canal to L 1, Th 10 and Th 6 were 1.30 ml kg^{-1} (95%CI 1.08-1.51), 1.57 ml kg^{-1} (95%CI 1.29-1.81) and 1.78 ml kg^{-1} (95%CI 1.52-2.08), respectively. The median volumes of the epidural space per vertebral segment were Thoracic: 0.60 ml (95%CI 0.38-0.75); Lumbar: 1.18 ml (95%CI 0.94-1.43) and Caudal: 0.85 ml (95%CI 0.56-1.18).

Conclusions. The spinal volumes of interest show a linear correlation to height and weight whereas a curvilinear correlation was found for age. The volume of the epidural space per segment was found to be significantly higher at the lumbar level compared with the caudal and thoracic levels.

Key words: anaesthesia, caudal; anatomy, cross-sectional; epidural space; magnetic resonance imaging; paediatrics

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Editor's key points

- Data concerning the intraspinal volume, and particularly that of the caudal epidural space, are sparse.
- Choice of local anaesthetic volume for caudal epidural blockade is largely empiric.
- In the current study the volumes of various caudal spaces were measured with MRI.
- Linear correlations between the caudal epidural volume and patient height and weight were found.

After its initial description by Campbell in 1933,[1] caudal blockade has become the most frequently performed regional anaesthetic technique in children.[2 3] Despite its long tradition the volume dosing of caudal blockade has mainly been based on purely empiric data[4] or has been derived from early reports using slightly unclear study designs.[5–7] More contemporary attempts at clarifying the injected volume *vs* cranial spread relationship, using radiographic methods, have largely failed to verify the results of these earlier publications.[8–12] However, recent studies have produced evidence that the final distribution involves two separate phases of bulk flow of the injected local anaesthetic; the initial phase caused by the injection itself and a secondary phase cause by a bidirectional flow of cerebrospinal fluid (coined "the CSF rebound mechanism").[13]

The volume of the caudal space has previously been determined from MRI scans in adults [14] and block-related parameters based on MRI (however, not including volume determinations) have previously been published.[15] Hypothetically it would be very useful to determine the baseline volume of the caudal-epidural space when attempting to provide a more scientific based rationale for appropriate volume dosing regimens. Thus, the aim of the present study was to assess relevant volumes of the spinal canal and caudal space in young children (<three yr of age), derived from MRI scans of the spinal structures.

Methods

This retrospective study was approved by the Regional Ethics Committee (EPN No: 2014/780–31/1, Chairman: E.Lindeblad).

The PACS (picture archiving and communication system) at the Dept of Paediatric Radiology at Astrid Lindgren Children's Hospital, Karolinska University Hospital, Stockholm, Sweden, was searched for MRI scans in children aged zero to three yr, which included appropriate visualization/MRI sequences of the spine and sacrum and where the radiologists report had classified the spine and sacrum as being structurally/anatomically normal. Twenty MRI scans, performed on various indications (mild neurological symptoms n = 7, skin lesions n = 3, poor neurological development n = 3, other n = 7) were collected from the MRI database.

Volume determinations based on MRI

The scans were all performed using a 1,5 Tesla MRI scanner (Achiva dStream, 1,5 Tesla, Philips Healthcare, Best, Netherlands). Each MRI investigation (T1W TSE and T2W TSE, with or without fat saturation) consisted of 18-39 axial slices with a slices thickness that varied between 3-5 mm. The assessments were made on both the T1 and T2 weighted axial images. The mean of each measurement was taken as the final value (T1W + T2W)/2). The adequacy of the delineation of the various structures was double-checked by a senior radiologist (author TF).

On each axial slice the following anatomical structures were marked if present:

a. The spinal canal or in more inferior slices the caudal space.
b. The dura mater.
c. The spinal cord.

Ad a: The caudal limit was defined as the most caudad epidural fat identified on sagital T2W TSE, corresponding to the centre of the caudal hiatus. The rostral limit was defined as the middle of the disc in between Th 6 and Th 5. The outer boundary of the spinal canal was easily determined in all slices where the dural sac was completely encircled by bone/cartilage. However, in slices taken at the level of the intervertebral foramen the delineation of the spinal canal was less self-evident. As to our knowledge no universally accepted definition of the spinal canal exists, we decided to use an arbitrary definition that would allow a clear and reproducible template for delineating the spinal canal in such slices: The dorsal protuberances of the vertebral body were marked bilaterally and subsequently a line was dropped in a straight dorsal direction. This line was then taken as the lateral boundary of the spinal canal in these MRI slices (Fig. 1).

The Osirix 5.6, 32 bit software (Pixmeo SARL, Bernex, Switzerland) was used to outline the various structures and subsequently calculate the various volumes from each slice.

Directly assessed volumes: volume of spinal canal/caudal space, volume of the dural sac and volume of spinal cord

Based on the plotting of the spinal canal/caudal space, the dura mater and the spinal cord on each individual horizontal segmental slice the volume of these three volume parameters could be determined, by multiplying the segmental area with the height of each horizontal segmental slice. By adding all

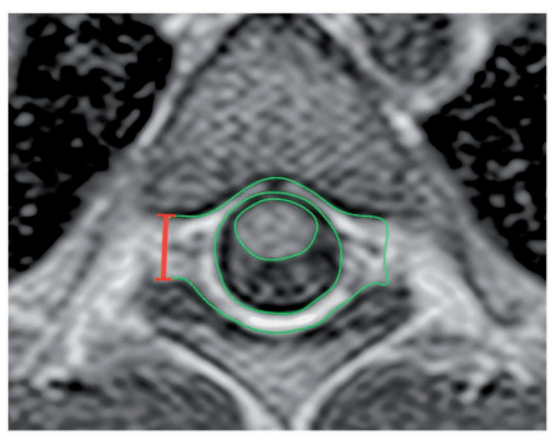

Fig 1 MRI scan illustrating the determination of the epidural space. This slice is taken at the level of the intervertebral foramina. The lateral boundary of the epidural space is delineated as described in the Methods section.