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ORIGINAL ARTICLE

Where is the apex of the sacral hiatus for caudal epidural block in the pediatric population? A radio-anatomic study

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Abstract
Purpose Caudal epidural block (CEB), administered through the sacral hiatus, is a regional anesthetic technique commonly used in children. To facilitate and optimize pediatric CEB, morphometric data that may be important for the sacral hiatus have been obtained using multidetector computed tomography (MDCT).
Methods This study is the first radio-anatomic study designed to address this topic in children. Images of 79 children (39 girls and 40 boys between 1 and 9 years old) were divided into three groups according to age [group I (ages 1–3), group II (ages 4–6), and group III (ages 7–9)] and were retrospectively examined. Data were gathered via 3D volume-rendered images. Measurements included the height and width of the sacral hiatus, S2–S4 (sacral vertebra) distance, the distances between the poles of the unfused spinous process of each sacral vertebra, and the dimensions of an imaginary triangle formed between the right and left posterior superior iliac spines (PSIS) and the apex of the sacral hiatus.
Results The most frequently fused spinous process was at S2 level. The mean S2–S4 distance was 1.36 cm for group I, 1.78 cm for group II, and 2.17 cm for group III. There was not the imaginary equilateral triangle used in the method of finding the sacral hiatus for CEB, and the apex of this triangle did not occur at the standard level (S4) in most of the children. It was observed that the apex deriving from the most distal fused spinous process was at the level of S2 in one of two children.
Conclusion Dural puncture is inevitable for CEB applied at the S2 level. Consequently, CEB should be applied below this level (range, 1.36–2.17 cm) from the midpoint of the interspinous distance between the PSIS (at the same level with S2) in children aged 1–9 years.

Keywords Regional anesthesia · Caudal epidural block · Landmarks · Posterior superior iliac spine · Sacral hiatus

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Introduction

The caudal epidural block (CEB) is the most widely used regional anesthetic technique for any procedure on the lower part of the abdomen and lower limbs in pediatric patients [1, 2]. Despite its frequent use and many years of experience, accidental dural puncture and intrathecal injections with CEB do occur [3]. The extraordinary formation of the sacral structure has been responsible for these complications [3, 4]. Thus, knowledge of the anatomy of the sacral canal is important for successful and safe use of CEB in pediatric patients.

The sacral hiatus is located in the caudal region of the sacrum [4, 5], and the remnants of the inferior articular process, which are called the sacral cornua, elongate down both sides of the sacral hiatus [6]. The sacral hiatus results from failure of a midline fusion of the lamina of the fifth, or sometimes the fourth, sacral vertebra [7]. This inverted U-shaped space is covered at its posterior aspect only with skin, subcutaneous fat tissue, and the sacrococcygeal ligament [4, 6].

Successful CEB requires proper placement of the needle into the epidural space after penetrating the sacrococcygeal ligament [8, 9]. To accomplish this placement, the sacral hiatus should be correctly determined after palpating the sacral cornua [2, 6, 9]. In adults, an important indicator for locating the hiatus can be found by drawing an inverted equilateral triangle [6]. However, the anatomy of the sacral canal and dural sac, especially in fetuses, infants, and children, differs from that in adults [10, 11].

Although numerous studies of adults, based on dry bone [4, 6, 12], on cadavers [8], and on radiologic findings [7, 13], have been undertaken to determine anatomical points for CEB, few studies have been performed in pediatric populations [2, 14, 15]. Multidetector computed tomography (MDCT) is a new, powerful, reliable, and noninvasive technique for visualizing unique anatomical details [16]. To date, there have been no relevant anatomical studies concerning CEB in the pediatric population using MDCT. The present retrospective study addressed these main questions: Where actually is the apex of the sacral hiatus for CEB in children? Where should CEB be applied?

Methods

After receiving approval from the Institutional Review Board (Ref: B.30.2.SEL.0.20.71.00.281/986), abdominal MDCT images of 79 (39 female and 40 male, 1–9 years of age) consecutive pediatric patients with suspected urethral or ureteral stones, abdominal pain, abdominal or pelvic masses, or an ectopic pancreas were retrospectively reviewed from the Radiology Department of Meram Faculty of Medicine, Necmettin Erbakan University, Konya, Turkey. The MDCT images of patients who had a history of trauma, previous operations, or visible bone deformities were excluded from the study. The pediatric patients were divided into three groups according to age (in years) as follows: group I (ages 1–3), group II (ages 4–6), and group III (ages 7–9). These divisions were created because the vertebral arch unites with the vertebral corpus between the second (for ages 1–3) and fifth (for ages 4–6) years, and the two sides of the vertebral arch combine dorsally in the eighth year (for ages 7–9) [5].

The MDCT scans were provided with a 64-slice CT scanner (Somatom Sensation 64; Siemens Medical Solutions, Forchheim, Germany). The images were obtained in a neutral supine position, without rotation, flexion, or extension, to provide standardized measurements. The images were imported into the Leonardo Workstation (Vitrea 2; Vital Images, Minneapolis, MN, USA) and were combined to create three-dimensional (3D) reconstructions. All the measurements were obtained by visual estimation of the determined points at an approximate window setting and level setting. The dimensions were measured using 3D volume-rendered images. For accuracy, dot cursors were placed in identical positions on corresponding axial, coronal, and sagittal images for measurement on 3D volume-rendered images [17]. The start and end points of the linear measurements of the images were determined with the internal digital caliper tool included in the Workstation software. The software (syngommwp VE 30A, syngo VE32B) calculated all the measurements, which were recorded in centimeters.

The parameters determined from the 3D volume-rendered images were as follows.

- Height of sacral hiatus (SHH): The distance between the estimated apex (S4) of the sacral hiatus and the sacral apex, from posterior coronal images (Fig. 1).
- Width of sacral hiatus (SHW): The intercornual distance, from posterior coronal images (Fig. 1).
- Height of sacral canal (SCH): The midline distance between the upper and lower margins of the sacral canal, from posterior coronal images (Fig. 1).
- S2–S4 distance: The midline distance between the S2 spinous process and the S4 spinous process.
- Distance between the poles of the unfused spinous process of each sacral vertebra occurring from failure of midline fusion (SF I–V): The distance between the poles of the unfused spinous process, from posterior coronal images (Fig. 2).

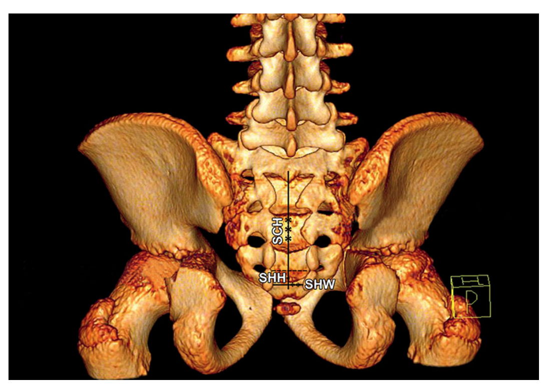

Fig. 1 Height of the sacral canal (*SCH*) (*triple asterisk*); height of the sacral hiatus (*SHH*) (*single asterisk*); width of the sacral hiatus (*SHW*) (*double asterisk*)

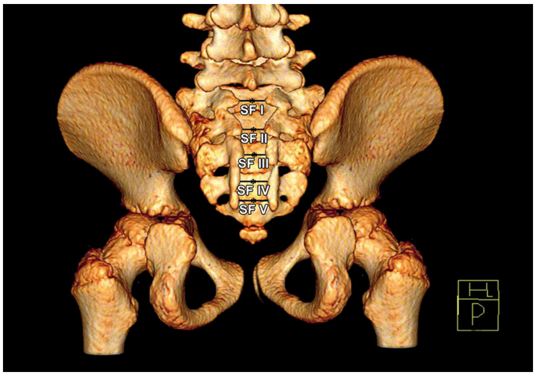

Fig. 2 Distance between the poles of the unfused spinous process of each sacral vertebra resulting from failure of midline fusion (SF I, SF II, SF III, SF IV, SF V)

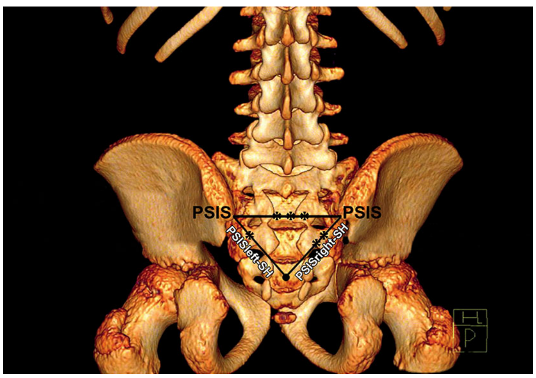

Fig. 3 Distance between posterior superior iliac spines (*PSIS*) (*triple asterisk*); distance between right posterior superior iliac spine and the imaginary apex (*filled circle*) of the hiatus (*PSISright-SH*) (*double asterisk*); distance between left posterior superior iliac spine and the imaginary apex (*filled circle*) of the hiatus (*PSISleft-SH*) (*single asterisk*)

- Distance between posterior superior iliac spines (PSIS): The interspinous distance between the posterior superior iliac spines, from posterior coronal images (Fig. 3).
- Distance between right posterior superior iliac spine and apex of the hiatus (PSIS right-SH): The distance between the right posterior superior iliac spine and the apex of the sacral hiatus, from posterior coronal images (Fig. 3).
- Distance between left posterior superior iliac spine and apex of the hiatus (PSIS left-SH): The distance between the left posterior superior iliac spine and the apex of the sacral hiatus on posterior coronal images (Fig. 3).

Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows, version 17.0 (SPSS, Chicago, IL, USA). A sample Kolmogorov–Smirnov test was conducted to determine whether the continuous numerical data were normally distributed. Comparisons of the mean data according to sex were analyzed using Student's *t* test with independent groups. Comparisons of the mean data according to age groups were performed using a one-way analysis of variance (ANOVA) with a Tukey's HSD (honestly significant difference) post hoc test. Statistical significance was defined as $P < 0.05$.

Results

The mean ages were 5.30 ± 2.5 and 4.51 ± 2.4 years for boys and girls, respectively, and there was no significant difference between sexes relative to age ($P > 0.05$). Table 1 presents comparisons of the mean data for the following parameters in each group stratified by sex: SHH,

Table 1 Comparison of data obtained according to sex and age (in years) group (mean ± SD, cm)

Parameters	Group I (ages 1–3)			Group II (ages 4–6)			Group III (ages 7–9)		
	Female ($n = 14$)	Male ($n = 12$)	*P*	Female ($n = 16$)	Male ($n = 15$)	*P*	Female ($n = 9$)	Male ($n = 13$)	*P*
SHH	1.00 ± 0.21	0.89 ± 0.17	0.163	1.14 ± 0.29	1.05 ± 0.26	0.424	1.19 ± 0.22	1.37 ± 0.25	0.102
SHW	1.12 ± 0.25	1.22 ± 0.15	0.245	1.23 ± 0.56	1.31 ± 0.22	0.636	1.18 ± 0.34	1.24 ± 0.28	0.649
SCH	3.08 ± 0.51	2.93 ± 0.41	0.452	3.71 ± 0.42	3.83 ± 0.57	0.519	4.23 ± 0.71	4.51 ± 0.62	0.333
S2–S4 distance	1.41 ± 0.11	1.32 ± 0.10	0.275	1.72 ± 0.14	1.85 ± 0.18	0.493	1.97 ± 0.13	2.23 ± 0.15	0.327
SF I	0.67 ± 0.37	0.86 ± 0.72	0.475	0.55 ± 0.37	0.73 ± 0.50	0.508	**One patient**	0.78 ± 0.47	0.659
SF II	0.84 ± 0.30	0.34 ± 0.15	**0.001**	0.61 ± 0.33	0.59 ± 0.38	0.925	**Zero patient**	0.80 ± 0.32	–
SF III	0.70 ± 0.29	0.68 ± 0.32	0.884	0.86 ± 0.50	0.77 ± 0.33	0.644	0.73 ± 0.25	0.63 ± 0.41	0.649
SF IV	0.85 ± 0.40	1.17 ± 0.28	**0.036**	1.14 ± 0.30	1.05 ± 0.39	0.543	1.13 ± 0.28	1.06 ± 0.17	0.548
SF V	1.12 ± 0.25	1.22 ± 0.15	0.250	1.14 ± 0.30	1.24 ± 0.33	0.373	1.18 ± 0.34	1.19 ± 0.36	0.962

SHH height of sacral hiatus, *SHW* width of sacral hiatus, *SCH* height of sacral canal, *SF* distance between the poles of the unfused spinous processes (I–V)

Bold indicates $P < 0.05$; zero patient and one patient represent no data

Table 2 Comparison of data obtained according to sex and age groups (mean ± SD, cm)

Parameters	Group I (ages 1–3 years)			Group II (ages 4–6 years)			Group III (ages 7–9 years)		
	Female ($n = 14$)	Male ($n = 12$)	P	Female ($n = 16$)	Male ($n = 15$)	P	Female ($n = 9$)	Male ($n = 13$)	P
PSIS	4.60 ± 0.72	4.60 ± 0.49	0.993	5.66 ± 0.50	5.25 ± 0.50	**0.033**	5.64 ± 0.55	6.18 ± 0.53	**0.032**
PSISright-SH	3.18 ± 0.72	2.99 ± 0.70	0.518	3.56 ± 0.63	3.60 ± 0.61	0.874	4.09 ± 0.75	4.20 ± 0.39	0.652
PSISleft-SH	3.18 ± 0.72	3.00 ± 0.70	0.526	3.42 ± 0.37	3.62 ± 0.62	0.269	4.09 ± 0.72	4.20 ± 0.39	0.655

PSIS distance between the posterior superior iliac spines, *PSISright-SH* distance between the right posterior superior iliac spine and the apex of the hiatus, *PSISleft-SH* distance between the left posterior superior iliac spine and the apex of the hiatus

Bold indicates $P < 0.05$

Table 3 The number of cases with fused spinous processes, according to sex and age (in years) groups (S5 < S4 < S3 < S1 < S2)

	Group I (ages 1–3)			Group II (ages 4–6)			Group III (ages 7–9)			Total ($n = 79$)
	Female ($n = 14$)	Male ($n = 12$)	Total ($n = 26$)	Female ($n = 16$)	Male ($n = 15$)	Total ($n = 31$)	Female ($n = 9$)	Male ($n = 13$)	Total ($n = 22$)	
S1	4	3	**7**	11	6	**17**	8	6	**14**	**38 (48.1 %)**
S2	7	4	**11**	9	8	**17**	9	9	**18**	**46 (58.2 %)**
S3	4	1	**5**	8	4	**12**	4	9	**13**	**30 (37.9 %)**
S4	1	0	**1**	3	1	**4**	2	1	**3**	**8 (10.1 %)**
S5	0	0	**0**	0	0	**0**	0	0	**0**	**0 (0 %)**

Bold indicates total data

SHW, SCH, S2–S4 distance, and SF I–V. Significant differences were observed in group I for SF II and SF IV ($P < 0.05$). None of the data were significantly different in group II and group III (Table 1). In general, the mean measurements were larger in males than in females. No significant differences were observed ($P > 0.05$) between the sexes except for the distance between PSIS in groups II and III (Table 2).

The number of cases with a fused spinous process at each sacral vertebra level was, from least to most, S5 < S4 < S3 < S1 < S2, according to age groups. The total fused spinous process regardless of sex and age group was found to be at the level of S1 in 38 children (48.1 %), at S2 in 46 (58.2 %), at S3 in 30 (37.9 %), at S4 in 8 (10.1 %), and at S5 in 0 (0 %) (Table 3). The distance between S2 level estimated to be the dural termination and S4 level imagined to be the apex of the sacral hiatus was measured. This mean distance was 1.36 ± 0.10 cm for group I (females 1.41 ± 0.11–males 1.32 ± 0.10), 1.78 ± 0.16 cm for group II (females 1.72 ± 0.14–males 1. 85 ± 0.18), and 2.17 ± 0.14 cm for group III (females 1.97 ± 0.13–males 2.23 ± 0.15) (Fig. 4).

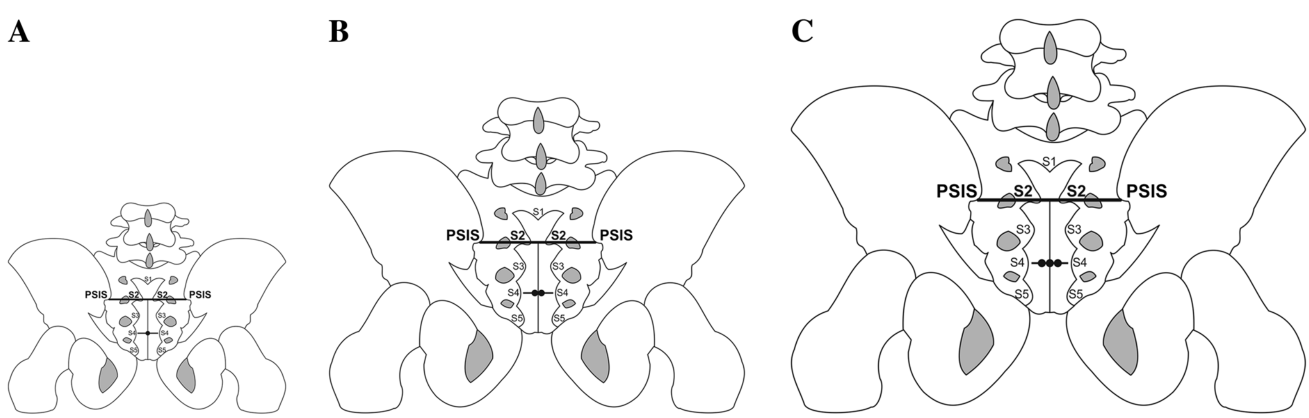

Fig. 4 Distance between S2 level estimated to be the dural termination and S4 level imagined to be the apex of the sacral hiatus (S2–S4 distance): *single filled circle* for group I (**a**), *double filled circle* for group II (**b**), and *triple filled circle* for group III (**c**). Caudal epidural block (CEB) should be applied below the level (range, 1.36–2.17 cm) from the midpoint of the interspinous distance between the PSISs

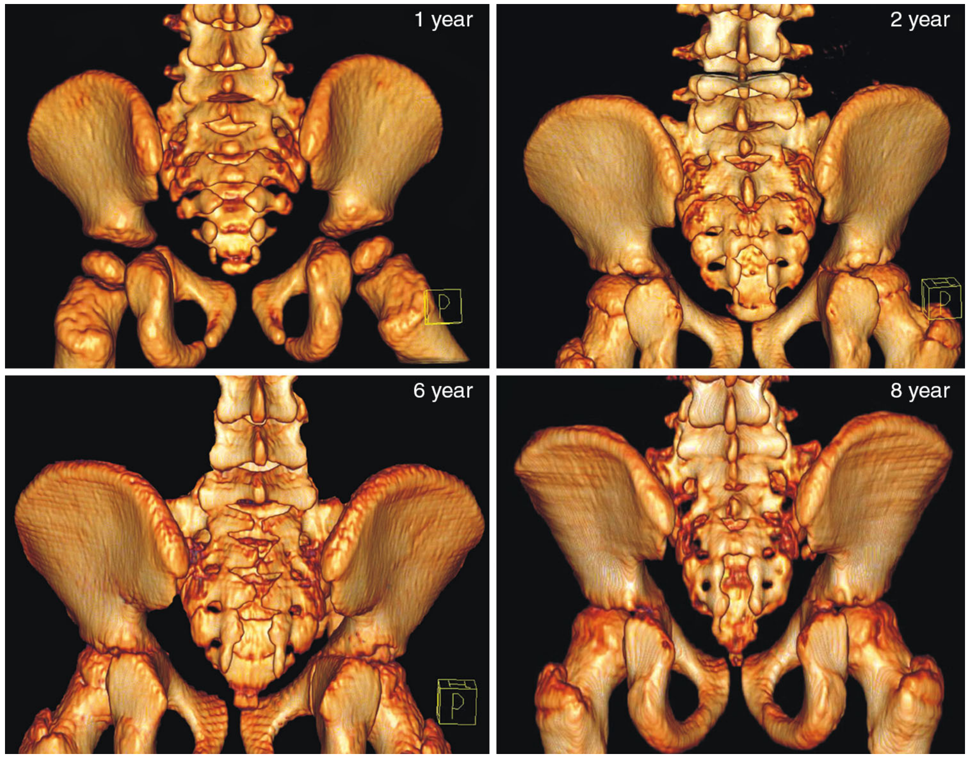

Fig. 5 In males: images of incomplete sacral canal and sacral hiatus occurring from failure of midline fusion in various age groups (1, 2, 6, and 8 years old)

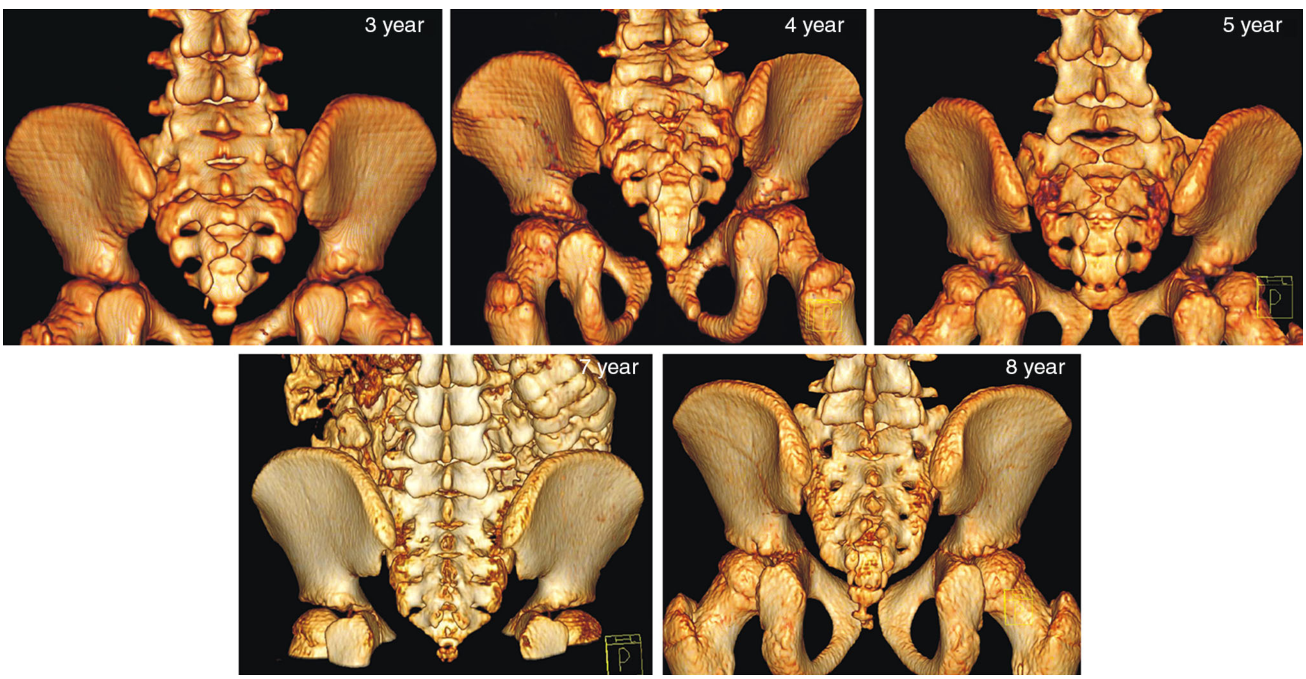

Fig. 6 In females: images of incomplete sacral canal and sacral hiatus resulting from failure of midline fusion in various age groups (3, 4, 5, 7, and 8 years old)

Discussion

The apex of the sacral hiatus and the termination of the dura show wide variation at sacral vertebral levels. It was reported that the end of the dural sac is located at the S4 level just after birth, then ascends to the S2 level as the child grows [18]. In a detailed fetal study, Aggarwal et al. [10] detected that the dural sac terminated at the level of S1 in 12.82 % of cases, at the S1–S2 junction in 15.38 %, at S2 in 51.28 %, at the S2–S3 junction in 15.38 %, and at S3 in 5.1 %. The apex of the sacral hiatus was also found to be at the level of S2 in 5.1 % of cases, the S2–S3 junction in 5.1 %, S3 in 58.97 %, the S3–S4 junction in 17.94 %, and S4 in 12.82 %. Consequently, termination of the dural sac was observed at S2 in most of the fetuses, whereas the apex of the sacral hiatus was at S3 in most cases. These findings indicate that, in small children, the distance between the sacral hiatus and the end of the dural sac is relatively short. In our study, the imagined level to be the apex of the sacral hiatus was the most distal sacral spinous process, which was fused the earliest. The fused spinous process was detected to be at the level of S1 in 48.1 %, S2 in 58.2 %, S3 in 37.9 %, S4 in 10.1 %, and S5 in 0 %. In 39 fetuses with crown–heel length between 33 and 50 cm (gestational age, 7–9 months), Aggarwal et al. [10] reported that the distance between the apex of the sacral hiatus and termination of the dura ranged from 3 to 13 mm, with a mean of 6.49 ± 2.84 mm. In addition, it was observed that this distance was in the range of 4.5–6.05 cm in adults [19] and 3.14 cm in children [2]. Therefore, we measured S2–S4 distance and found the mean distance was 1.36 cm for group I, 1.78 cm for group II, and 2.17 cm for group III. In our study, the distance between the S2 level estimated to be the dural termination and the S4 level imagined to be the apex of the sacral hiatus ranged from 1.36 to 2.17 cm in children aged 1 to 9 years.

Koo et al. [11] performed an ultrasound study to evaluate the effect of body position in locating the termination of the dural sac in infants and young children. This study has shown that the level of the end of the dural sac moves cephalad significantly in relationship to the vertebra during back flexion. The median vertebral level of the end of the dural sac changed from the middle third of S2 (neutral position) to the upper third of S2 after assuming a flexed position. In the neutral supine position, we observed that PSIS was at the same level as the spinous process of the S2 vertebra (approximately the same location as the termination of the dural sac), similar to adults (Fig. 4). These points were important for estimating the end of the dural sac.

The intercornual distance was found to be consistent with other studies. Based on sonographic evidence, Park et al. [15] reported that the median intercornual distance was 17.0 (range, 9.6–24.6) mm in children aged 2–84 months, and that this distance was observed to be 6.30 (range, 2.48–8.90) mm in fetuses [10]. In our study, the intercornual distance was 11.7–12.7 mm in children aged 1–9 years. Generally, a 22-gauge (~0.644 mm) needle is used for CEB. Hence, if the intercornual distance were insufficiently wide, it would be difficult to pass the needle into the sacral canal.

In our study, knowledge regarding sacral hiatus was provided with MDCT for the purpose of CEB, and the following conclusions were reached. The sacral cornua was not evident in children. The median sacral crest formed by the spinous processes did not occur. An incomplete sacral canal appeared because of the unfused spinous processes of each sacral vertebra, occurring from failure of the midline fusion. It was not possible to state the palpable apex of the sacral hiatus at the standard level (S4) because the level of the fused sacral spinous processes was different for each child (Figs. 5, 6). Therefore, we observed that the traditional "equilateral" triangle used to locate the apex of the sacral hiatus did not occur. In our opinion, the point considered to be the apex was the most distal spinous process, which fused the earliest. The most frequent fusion was at the level of S2, which was the level of the estimated dural termination in one of two children. Thus, the possibility of puncturing the dura should be borne in mind because of the occurrence of unfused spinous processes. CEB should be applied below the level (which ranged from 1.36 to 2.17 cm) from the midpoint of the interspinous distance between the PSIS (at the same level as S2) in children aged 1–9 years (Fig. 4). However, many pediatric anesthesiologists use the triangle method to identify the sacral hiatus on a daily basis, and the incidence of dural puncture has been extremely rare. We believe that they performed CEB below an estimated distance considering the interspinous distance between PSIS (~S2 level).

Conflict of interest This research was not sponsored by an outside organization. We (all the authors) have agreed to allow full access to the primary data and to allow the journal to review the data if requested.

Ethical standards statement This study conformed to the Helsinki Declaration.

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