MK SCIENCE SET
OPEN ACCESS PUBLISHERS

ISSN: 3067-2376
Research Article

Journal of Comparative Medicine Research Reviews and Reports

Comparison of Palpation and Ultrasound for Sacral Cornua Identification and Evaluation of Caudal Epidural Anatomy in Children Aged 1-84 Months

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Submitted: 24 February 2025 **Accepted:** 03 March 2025 **Published:** 08 March 2025

https://doi.org/10.63620/MKJCMRRR.2025.1013

Citation: *Kaya, C., Kendigelen, P., Tutuncu, A. C., & Kaya, G (2025). Comparison of Palpation and Ultrasound for Sacral Cornua Identification and Evaluation of Caudal Epidural Anatomy in Children Aged 1-84 Months. J of Comp Med Res Rev Rep, 2(2), 01-08.*

Abstract

Objectives: The aim of this study is to compare the identification of the sacral cornua using palpation and ultrasound, and to evaluate sacrococcygeal area via ultrasound across different age groups of children.

Setting: *This study was conducted in Istanbul University Cerrahpasa, Istanbul, Turkey.*

Design: *This study included 348 children aged 1 to 84 months, who were divided into three age groups: 1-24 months, 25-48 months, and 49-84 months. Sacrococcygeal area was assessed using both palpation and ultrasound imaging. Palpation findings were categorized as 'good,' 'difficult,' or 'non-palpable.' Ultrasound imaging of the sacral cornua was classified as 'clear,' 'unclear,' or 'invisible.' Measurements taken included the inter-cornual distance, the antero-posterior diameter of the sacral canal, the distance from the skin to the sacral canal, and the distance from the dural sac to the cornua level.*

Results: *Palpation of the sacral cornua was rated as 'good' in 75.9% of patients, 'difficult' in 22.4%, and 'non-palpable' in 1.7%. All patients with 'good' cornua palpation were also classified as 'clear' on ultrasound imaging. Among the cases with 'difficult' palpation, 76% showed a 'clear' ultrasound image, while 24% were 'unclear'. Only one patient had 'invisible' cornua on ultrasound. Across all patients, the mean (± SD) inter-cornual distance, anteroposterior diameter of the sacral canal, and the distance between the skin and sacral canal were 1.19 ± 0.11 cm, 0.33 ± 0.06 cm, and 0.46 ± 0.14 cm, respectively. The mean distance from the dural sac to the cornua level was 3.72 ± 1.64 cm, and this distance increased significantly with age (P < 0.01).*

Conclusions: *Ultrasound is a valuable tool for identifying the sacral cornua, especially when palpation is difficult, and offers reliable, detailed information on sacral anatomy.*

Keywords: Pediatrics, Caudal anesthesia, Analgesia, Regional anesthesia, Sacrococcygeal region, Ultrasound; Anatomy

Strengths and Lımıtatıons of Thıs Study

- In reference to the limitations of our study, we could firstly mention the high numbers of male patients in comparison to the female patients. However, given the similarity of the pelvic structure of the children in the 3 age groups, this gender-based difference should not affect our measurements.
- Secondly, determining the termination point of the dural sac and checking the possibility of any anomalies, detecting the position of the cornua with ultrasound, all of which require experience.

Introduction

Caudal block is a frequently preferred intervention, mostly in sub umbilical surgery, in being an easily applicable method guided by distinct anatomical structures. Technically, this involves palpation of both sacral cornua to identify the sacral hiatus, with the patient in the prone or lateral decubitus position [1].

However, palpation may be challenging due to high body weight, young age, or anatomical variations. Caudal block can fail if the local anesthetic is given to the wrong sites with the penetration of the superficial soft tissue or the intravascular, intraosseous or intrathecal areas. Such incidences, although rare, can have serious com-plications such as systemic toxicity or total spinal anesthesia [2-4].

Ultrasonography has emerged as a non-invasive imaging modality that enables real-time visualization and assessment of anatomical structures. This advancement has led to a notable increase in the utilization of ultrasound-assisted caudal blocks, aiming to enhance the safety and success of interventions [5]. However, previous research indicates significant anatomical distinctions between pediatric and adult patients [6]. These variances arise from the ongoing growth and development period in children, resulting in variations among different age groups.

In this study, our primary aim was to compare the methods of palpation and ultrasound imaging in the detection of the cornua used to find the needle insertion site during caudal block. Secondly, the sacrococcygeal area was examined using ultrasound in both transverse and longitudinal sections in children aged 1 to 84 months, covering the age range most commonly targeted for caudal block procedures. This examination aimed to investigate anatomical variations across different age groups.

Materials and Methods

Before patient enrolment, this prospective observational study was approved by the institutional ethics committee of Cerrahpasa Medical Faculty documented as No: 72109855-604.01.01-103424, registered at clinicaltrials.gov (NCT03825172). Between January 2019 and January 2020, 348 children aged 1-84 months with ASA I-II and meeting the criteria of not having musculoskeletal, spinal anomalies, sacral dimples, history of prematurity or a known syndromic illness were enrolled in the study after the written informed consent of the parents. Three age groups were formed as the Groups 1, 2 and 3 to include, respectively, the 1-24 month, the 25-48 month and the 49–84-month-old patients (Figure 1).

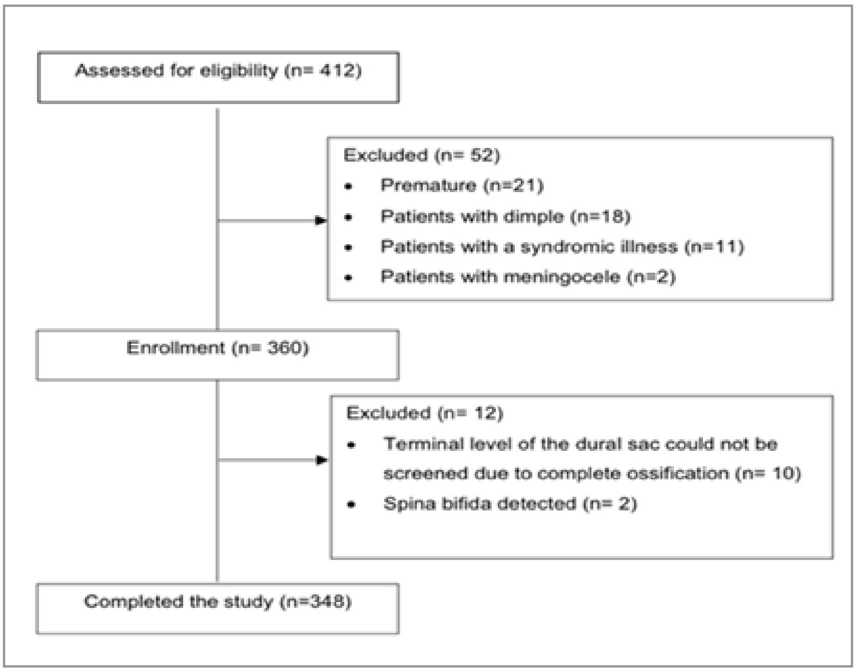

Figure 1: Flow Diagram of The Study

After induction of general anesthesia, patients were placed in the lateral decubitus position with hips and knees in 90-degree flexion. The caudal area was then assessed through visual inspection and palpation. The cornua were classified as "good" when both cornua were easily palpable, as "difficult" if one or both were palpated with difficulty or one could not be palpated at all and as "non-palpable" if both could not be palpated. Palpation was performed by two experienced anesthetists, and classification was determined by joint consensus. Subsequently, the patients were investigated by ultrasound for the sacral structures critical for caudal block process.

All ultrasound investigations were carried out by the same anesthetist in the presence of an observing anesthetist with experience in the caudal applications of ultrasound. The ultrasound (Esaote Europe BV, Maastricht, The Netherlands) was used at a frequency of 12-18 MHz with the linear probe to visualize the caudal area. Firstly, a transverse section was obtained by positioning the probe on the spine over both cornua to capture the characteristic 'toad face' image, and the following structures were identified (Figure 2).

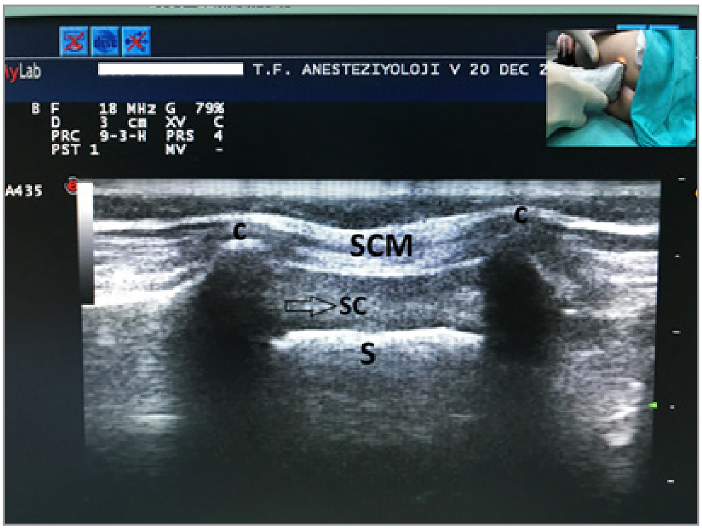

Figure 2. Transverse section of caudal ultrasonography at cornua level. Abbreviations: C, Cornua; SC, Sacral Canal; S, Posterior wall of the sacrum; SCM, Sacrococcygeal membrane.

Cornua: The transverse section was utilized to identify the highest points of both cornua, enabling the measurement of the distance between them.

If both shadows were clearly visible, the cornua were classified as 'clear.' Weak unilateral or bilateral shadows, believed to correspond to the cornua, were classified as 'unclear.' If no bone shadows were present, the image was categorized as 'invisible'.

Sacrococcygeal Membrane (SCM): SCM appears as a thin, shiny strip in the transverse section covering the sacral hiatus on posterior sacral canal. We opted to measure the distance from the skin to the epidural space instead of directly assessing the thickness of the SCM due to challenges in distinguishing it from the subcutaneous tissue in transverse sections. Posterior sacral bone: In transverse imaging, it exhibits a distinct bright white appearance. It serves as the anterior wall of the sacral canal within this specific area.

Antero-Posterior Diameter of Sacral Canal: It is the distance between the SCM and the posterior sacral bone measured on transverse section.

Once the transverse section assessment was completed, the linear probe was rotated 90 degrees to obtain a longitudinal section. Subsequently, the dural sac, sacral epidural area, sacral vertebral bodies, intervertebral spaces and, cornua level were clearly defined. The distance between cornua level and end point of dural sac was measured (Figure 3).

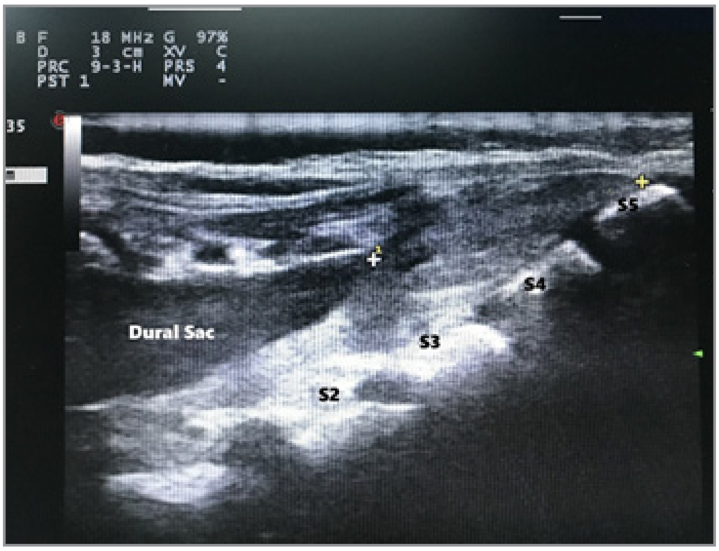

Figure 3: Longitudinal Section of Sacrococcygeal Ultrasound. +…+ Shows the Distance Between the Terminal Point of The Dural Sac and The Cornua Level.

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) v 15.0 software (SPSS, Inc., Chicago, IL, USA). The descriptive statistics for the categorical variables were expressed in numbers and percentages and the numerical variables were expressed in terms of the mean, standard deviation (SD), the minimum and the maximum, the median, interquartile range (IQR), and the 95% confidence interval (95% CI). As the numerical variables did not meet the assumptions for normal distribution, comparisons of more than 2 groups were carried out with the Kruskal-Wallis test. The subgroup analyses for the nonparametric test were made using the Mann-Whitney U test with the Bonferroni correction. The ratios in the groups were compared with the Chi-Square test. Since the relationships between the numerical variables did not meet the parametric test conditions, correlations were determined by calculating the Spearman correlation coefficients. P value of <0.05 as accepted to indicate statistical significance. Clinical significance between groups was indicated by effect size.

Results

As seen in flow chart, 412 children assessed for eligibility. After the exclusion criteria, 360 children were enrolled for sacrococcygeal ultrasonography. In 10 children, termination level of the dural sac could not be evaluated due to ossification and in 2 children spina bifida was detected by ultrasonography. As a result, 348 children were included in this study (Figure 1).

The demographic and clinical data on the 348 children included in the study are shown in Table 1.

Table 1: Patient Characteristics

	Total	1-24 m	25-48 m	49-84 m
Sample size, n, (%)	348	136 (39.1)	108 (31.0)	104 (29.9)
Age (months)	30	11	34.5	64
Median (IQR)	(14-51)	(5-16)	(29-39)	(53.25-74.75)
Sex, n (%)				
Male	251 (72.1)	99 (72.8)	82 (75.9)	70 (67.3)
Female	97 (27.9)	37 (27.2)	26 (24.1)	34(32.7)
Weight (kg)				
Mean (SD)	13.8 (5.9)	8.9 (2.9)	13.9 (2.7)	20.3 (4.8)
(Min-Max)	(3-40)	(3-18)	(10-21)	(11-40)
Height (cm)				
Mean (SD)	92.5 (19.2)	75.2 (14.1)	95.6 (9.6)	112.1 (9.4)
(Min-Max)	(48-140)	(48-105)	(70-130)	(85-140)
ASA classification, n, (%)				
I	273 (78.4)	114 (83.8)	86 (79.6)	73 (70.2)
II	75 (21.6)	22 (16.2)	22 (20.4)	31 (29.8)

Abbreviations: SD, Standard deviation; IQR, interquartile range; ASA, American Society of Anesthesiologist; m, months

Table 2 summarizes changes in the palpability and ultrasound visibility of the sacral cornua across different age groups. Overall, palpation of the sacral cornua was rated as "good" in 75.9% of patients, "difficult" in 22.4%, and "non-palpable" in 1.7%. The percentage of patients with "good" palpation was 65.4% in Group 1, 81.5% in Group 2, and 83.7% in Group 3. Group 1 had a significantly lower rate of "good" palpation compared to Groups 2 and 3 (P < 0.01), while there was no significant difference between Groups 2 and 3 (P = 0.33). A statistically significant difference was observed overall across the three groups (P < 0.01). Only 6 patients had non-palpable cornua.

Ultrasound examination revealed that the cornua image was "clear" in 93.7% of all patients. Specifically, "clear" imaging was observed in 89% of Group 1, 96.3% of Group 2, and 97% of Group 3. The rate of "clear" ultrasound imaging was significantly lower in Group 1 compared to Group 3 (P = 0.04), with no significant differences between other subgroups. Only one patient had an "invisible" cornua image.

Table 2. Cornu palpations, ultrasonographic evaluations of cornu positions and changes with respect to age groupings

											Subgroup analysis		
Group (Age-month)		Total		1 (1-24m)		2 (25-48m)		3 (49-84m)			1-24 vs. 25-48m	1-24 vs. 49-84m	25-48 vs. 49-84m
CORNUA		n	%	n	%	n	%	n	%	pa	pb	pb	pb
Palpation	Good	264	75.9	89	65.4	88	81.5	87	83.7	<0.01c	0.01c	<0.01c	0.33

	Difficult	78	22.4	43	31.6	20	18.5	15	14.4				
	Non palpable	6	1,7	4	2.9	0	0,0	2	1.9				
Ultrasound image	Clear	326	93.7	121	89	104	96.3	101	97.1	0.04c	0.07	0.04c	1
	Unclear	21	6	14	10.3	4	3.7	3	2.9				
	Invisible	1	0.3	1	0.7	0	0	0	0				

Abbreviations: m, month

a: Kruskal Wallis test used to compare all of three groups

b: Subgroup analysis with Man Whitney U test (Bonferroni correction P<0.017)

c: Chi-square test used to compare proportion

All patients with "good" palpation had 100% "good" cornua imaging on ultrasound. Among patients with "difficult" palpation, 75.6% showed 'good' imaging, while 24.4% had "unclear" imaging. For those in whom the cornua were "non-palpable" (6 patients), 50% had 'clear' ultrasound imaging (Figure 4).

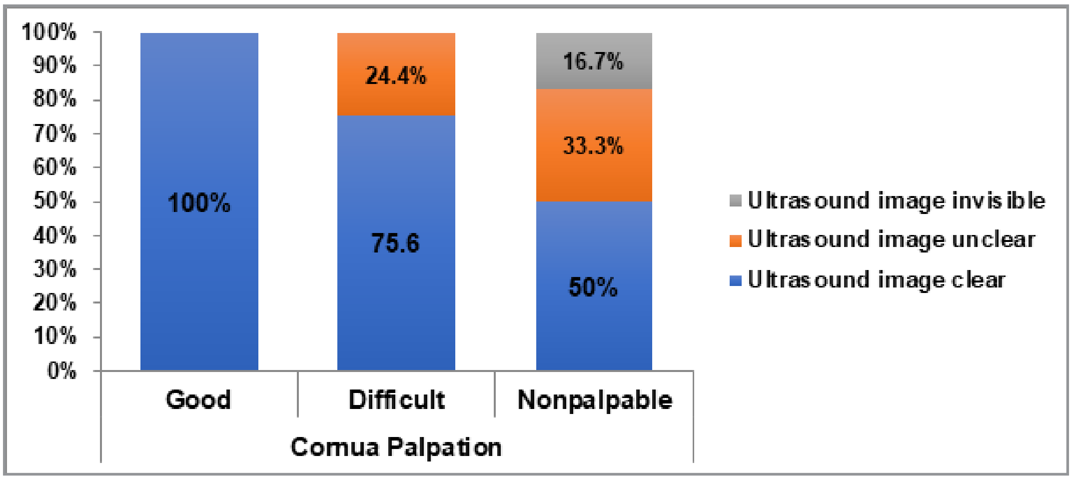

Figure 4: Ultrasound visibility of the cornua in patients classified with Good, Difficult, and Non-palpable Palpation.

The ultrasonographic measurements on the transverse and longitudinal sections of the caudal area and their variation with respect to age groups are shown in Table 3.

Table 3: USG Assisted Measurements on The Transverse and Longitudinal Sections.

			Age				Subgroup Analysis		
		Total	1-24m	25-48m	49-84m	Pa	1-24 vs.	1-24 vs.	25-48 vs.
		(n=348)	(n=136)	(n=108)	(n=104)		25-48m Pb	49-84m Pb	49-84m Pb
Inter-cornual distance	Mean(SD)	1.19(0.11)	1.13(0.19)	1.23(0.20)	1.23(0.20)	<0.001	<0.001	<0.001	0.42
(cm)	Median	1.21	1.14	1.22	1.28				
	IQR	1.06-1.33	0.98-1.26	1.08-1.36	1.12-1.37				
	95% CI	1.17-1.22	1.10-1.17	1.19-1.26	1.20-1.27				
Antero-posterior diameter of sacral canal	Mean(SD)	0.33(0.06)	0.32(0.05)	0.34(0.06)	0.32(0.05)	<0.01	<0.001	0.22	0.04
(cm)	Median	0.33	0.31	0.34	0.33				
	IQR	0.30-0.36	0.28-0.34	0.31-0.36	0.29-0.36				
	95% CI	0.32-0.33	0.31-0.33	0.33-0.35	0.31-0.33				
Distance from skin to sacral canal	Mean(SD)	0.46(0.14)	0.41(0.11)	0.46(0.13)	0.53(0.16)	<0.001	0.03	<0.001	<0.001
(cm)	Median	0.44	0.395	0.425	0.505				
	IQR	0.36-0.55	0.32-0.50	0.36-54	0.41-0.59				

	95% CI	0.45-0.48	0.39-0.43	0.43-0.48	0.49-0.56				
The distance between the dural sac terminal point and the cornua level (cm)	Mean(SD)	3.72(1.64)	3.11(1.53)	3.99(1.97)	4.30(0.95)	<0.001	<0.001	<0.001	<0.001
	Median	3.76	3.09	3.885	4.48				
	IQR	2.90-4.25	2.36-3.76	3.28-4.21	3.81-4.88				
	95% CI	3.54-3.90	2.85-3.37	3.61-4.37	4.10-4.49				

Abbreviations: SD, Standard deviation; IQR, interquartile range; SCM, sacrococcygeal membrane
a: Kruskal Wallis test used to compare all three groups
b: Subgroup analysis with Man-Whitney U test (Bonferroni correction p<0.017

Discussion

In the caudal block procedure, the epidural area is easily accessed through the sacral hiatus. This opening is formed by the non-fusion of the 5th vertebral arches, and in some cases, the 4th sacral vertebral arches. Although caudal block is implemented fast and easily, the highly variable anatomical structure of the sacrum affects its safe application [7]. In children the distance between the dural sac termination point and the sacral hiatus is shorter than in the adults and the resultant proximity can cause accidental perforation of the dura [8].

Understanding the anatomy for caudal block is critical for prevention of complications. Therefore, the anesthetists have to determine the correct and suitable position of the patient and make the appropriate markings if necessary.

In an ultrasound assisted study comparing straight position and flexion, it was shown that the dural sac progressed cranially with flexion. Giving the hip and knee flexion to the patients during caudal block was found to help gain distance by the caudal needle [9]. Therefore, in this study, all children were given a standard position during the ultrasound imaging. The measurements were taken with hips and knees flexed at a 90-degree angle; a positioning commonly employed in caudal block procedures. Since urological surgery is more frequent with male children for reasons of circumcision or orchiopexy, the number of male patients exceeded the female patients in this study. However, Adewale et al showed that MRI of the sacral anatomy did not show significant differences between male and female children [8].

In children, ossification of the sacral bone is completed around 8 years old [7]. Therefore, ultrasound can provide more detailed information in children compared to adults. After completed ossification, it may not be possible to screen the lower level of the dural sac by ultrasound hence, the upper age limit was accepted as 84 months. Ten patients near this upper age limit were excluded because the end of the dural sac was not visible on ultrasound. Additionally, palpation was done by 2 experienced anesthetists to avoid any bias and there was no any conflict during the classification.

Although palpating the cornua to determine the sacral hiatus is a commonly employed method by clinicians, it is crucial to acknowledge that not all anatomical markers providing this facility are uniform across all patients. Sekiguchi et al. reported only being able to palpate 19 of the cornua in 92 adult cadavers, while Aggarwal et al. achieved bilateral palpation in only 30 out of 49 adult cadavers [10, 11].

In another cadaveric study by Aggarwal et al., bilateral palpation was identified in 23 out of 39 fetuses (58.97%) that were at a gestational age of 7-9 months [12]. This underscores how ultrasound can be a viable alternative, while also considering the specific site of the sacral hiatus.

In our study, palpation of the sacral cornua was rated as 'good' in 75.9% of patients, and when investigated by ultrasonography, it was found to be 'clear' in 93.7% of these cases. Among patients whose cornua were rated as 'difficult' to palpate, ultrasound revealed 'clear' visualization in 75.6%, while 24.4% were 'unclear.' Of the six patients with non-palpable cornua, three had 'clear' visualization, two were 'unclear,' and one was 'invisible' on ultrasonography (Table 2). The effectiveness of ultrasound in imaging the caudal cornua was demonstrated by the fact that only one patient out of 348 had 'invisible' cornua, leading to the assumption that this patient may not have had developed cornua. Therefore, it can be concluded that in patients with developed cornua, ultrasound is unlikely to miss these structures. In summary, ultrasound proves to be a highly sensitive method for identifying the positions of the sacral cornua compared to palpation.

Additionally, there is relatively greater difficulty in detecting the cornua by palpation and ultrasound in the 1–24-month age group (Table 2). Given that the bone structure of infants is not fully developed and that anatomical markers may still be cartilaginous, this challenge may be due to the underdeveloped state of these structures in some patients, as well as the presence of presacral fat tissue that may obstruct palpation. Analysis of ultrasound images by age group revealed that the percentage of 'unclear' cornua was 10.3% in Group 1, decreasing to 3.7% in Group 2 and 2.9% in Group 3 (Table 2). This higher incidence of 'unclear' images in infants likely reflects the incomplete development of the cornua in this age group. However, the percentage of 'good' images remains high in Group 1, and given our experience with successful visualization in younger patients, ultrasound can be a valuable technique to guide anesthetists during caudal block procedures.

In our study, the mean inter-cornual distance in the entire patient group was 1.19 ± 0.11 cm, which was statistically less in the Group 1 in comparison to the two older groups (Table 3). The shortness of this distance would make entry into the sacral canal difficult implying that manipulation of the needle is more difficult in the small age group including the newborn [13].

The sacral canal should have the appropriate diameter for manipulating the needle with ease. Measurement of the antero-posterior diameter of sacral canal during ultrasound imaging on the transverse section gives important information to the physicians. Chen et al. measured the antero-posterior diameter of the sacral canal at the apex of the sacral hiatus and determined a mean value of 0.53 ± 0.2 cm in 47 adult patients being injected caudally for sciatica pain during caudal ultrasonography on the longitudinal section [14]. Despite previous findings indicating that the widest diameter of the sacral canal at the upper section of SCM according to the experience we have gained in this study, it is not always possible to obtain the image of the sacral hiatus apex on the longitudinal section in the pediatric patients [8,12].

Therefore, we have preferred to measure the antero-posterior diameter of the sacral canal from a specific image obtained at the cornua level on the transverse section which simulates the ‘’Toad’’ face (Figure 2). Therefore, our findings indicate a shorter sacral canal diameter. In our study the mean value of antero-posterior diameter was 0,33 ± 0.06 cm for all age groups. Interestingly, this distance was found to be wider in the 2nd group compared to the other groups, which can be considered as an anatomical variability finding (Table 3). It is very difficult to enter such a narrow canal with a needle. As a result, the frequent bone and subcutaneous penetration may be a sign of narrower canal which can be investigated with ultrasound.

The distance from the skin to the sacral canal is an important marker for directing the needle to the right point and making a safe block. Very thin subcutaneous tissue can cause inability to detect the fall when the needle passes through the SCM, which would also complicate retrieving the needle to the subcutaneous tissue for adjustment to another angle. However, it is not always possible to differentiate the subcutaneous tissue from the SCM with ultrasound. Therefore, we preferred to take these two structures together when making measurements (Figure 2). In our measurements, a notable and statistically significant increase in this distance was observed among older children (Table 3). This finding suggests a positive correlation between the child's age and the combined subcutaneous and SCM thicknesses, indicating that as the child's age advances, these thicknesses tend to increase.

One of the most feared complications of caudal block is penetration of the dural sac. Although rare it can result in the life-threatening advent of total spinal anesthesia [2]. Such complications are avoidable since ultrasound enables detecting the position of the dural sac and the proximity to the injection site in children (Figure 3). In our study the estimated mean distance between the termination points of the dural sac and the cornua level which is acceptable for site of injection was 3.72 ± 1.64 cm in children aged 1-84 months (Table 3). This measurement varied with age, such that the mean distance was 3.11cm, 3.99 cm and 4.30 cm, respectively in Groups 1, 2 and 3 the differences being statistically significant ($P<0.01$). These results indicate the necessity of care in order to prevent dural puncture in the infant group.

Conclusions

This study demonstrates that ultrasound is a highly effective tool for identifying the sacral cornua in pediatric patients, especially when palpation is challenging. Compared to palpation, ultrasound provides superior clarity of the sacral anatomy, with nearly all patients showing clear visualization. Subsequently, inter-cornual distance, combined subcutaneous tissue and sacrococcygeal membrane thickness, distance between dural sac level, and cornua level undergo modifications as individuals age.

Acknowledgments

We thank all staff of the department of anesthesia and operation theatre for their help in this study.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Ethics Approval

This study involves human participants and was approved by the institutional ethics committee of Cerrahpasa Medical Faculty documented as No: 72109855-604.01.01-103424.

Patient consent for Publication

Consent obtained directly from parents.

Contributors

CK, PK, ACT and GK were involved in the conceptualization of this research and the research design. CK, PK and ACT were involved in the data collection and extraction. CK and GK undertook the data analysis. CK, PK and GK wrote the initial draft of the manuscript. All authors have reviewed and approved the final manuscript and agreed to be accountable for all the work included. Guarantor: CK.

Data availability Statement

Available upon reasonable request.

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