

Comparison of the skin-to-epidural space distance at the thoracic and lumbar levels in children using magnetic resonance imaging

ABSTRACT

Background: Several studies have attempted to estimate the approximate distance from the skin-to-epidural space using different imaging modalities (computed tomography [CT], ultrasound, and magnetic resonance imaging [MRI]) and direct needle measurements. The objective of our study was to compare the distance from the skin to the epidural space (SED) at multiple levels, focusing on T₆₋₇, T₉₋₁₀, and L₂₋₃ using MRI.


Methods: After institutional review board (IRB) approval, sagittal T2-weighted MRI images of the spine of 108 children in the age group ranging from 3 months to 8 years undergoing radiological evaluation in the supine position at our institution were analyzed. The SED at T₆₋₇ and T₉₋₁₀ levels (straight and inclined) and SED at L₂₋₃ (straight) were determined and compared using repeated-measures ANOVA and paired *t*-tests with a Bonferroni correction for 10 pairwise comparisons (*P* < 0.005 was considered statistically significant).

Results: The average SED (measured straight and inclined) was 18.2 mm and 21.6 mm at T₆₋₇; 18.3 mm and 20.5 mm at T₉₋₁₀; and 21.8 mm (straight) at L₂₋₃. The repeated-measures ANOVA F-test indicated significant variability in SED (*P* < 0.001) among the 5 measurements obtained. At the *P* < 0.005 significance level, corrected for multiple comparisons, the SED (straight) at T₉₋₁₀ straight was shorter than the other measured distances.

Conclusion: The distance from the skin to the epidural space is not constant at various vertebral levels. At the levels measured, it was greatest at the lumbar level and at least at the thoracic level of T₉₋₁₀. A single predictive formula was not applicable for calculating the approximate SED at all vertebral levels.

Key words: Epidural anesthesia; lumbar epidural; thoracic epidural

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Introduction

Given its potential to provide effective analgesia, the use of epidural anesthesia continues to increase in pediatric-aged patients. Technical difficulties encountered in performing epidural anesthesia in children include smaller anatomical landmarks and shallower distances from the skin to the epidural space. Prediction of the approximate distance from the skin to the epidural space (SED) may provide useful information to increase the safety and success of the epidural catheter placement.^[1-3] Several studies have attempted to estimate the distance from the skin to the epidural space using direct needle measurement and imaging modalities (computed tomography [CT], ultrasound, and magnetic resonance imaging [MRI]).^[4-11] These studies have reported the SED at a single level and then proposed a mathematical formula for the estimation of this distance based on weight or age.

MRI derived measurements may be more accurate as it is highly sensitive for identifying the anatomy including the ligaments and remains the imaging modality of choice for injuries to the posterior longitudinal ligament, interspinous soft tissues, spinal cord lesions, and ligamentous injury.^[12-14] While MRI-measured SED at the thoracic and lumbar levels have been separately reported, none have compared the SED at the thoracic and lumbar levels in the same study cohort.^[10,11] Evidence for a consistent SED at different vertebral levels would be required to support the use of a single predictive mathematical formula as the epidural space may be accessed at various levels based on the clinical need. The objective of our study was to measure the SED at two thoracic levels [T₆-T₇, T₉-T₁₀] and one lumbar level [L₂-L₃] using MRI images.

Methods

The study was conducted at the King Fahad Medical City Hospital in Riyadh, Saudi Arabia. Institutional review board (IRB) approval for this retrospective study was obtained and the need for informed consent was waived. The study analyzed sagittal T2-weighted MR images of the spine of children in the age group ranging from 3 months to 8 years in the supine position. The cohort for the current study included data and MR images from patients who had been included in two previous studies.^[11,15] Patients with any history indicative of spinal pathology (scoliosis, tethered cord, spina bifida, myelomeningocele, tumors of the spinal cord or vertebral bodies, spinal metastatic disease) or poor image quality were excluded.

An internal measurement device was used to measure the SED (distance from the external skin edge to the dural side of the ligamentum flavum) with two measurements taken at the T₆₋₇ and T₉₋₁₀ interspaces as well as one measurement at L₂₋₃ interspace. At the T₆₋₇ and T₉₋₁₀ interspaces, the first measurement was taken perpendicular to the long axis of the vertebral body whereas the second measurement (inclined) was taken on a plane that would pass between the spinous processes with the measurement parallel to the spinous processes [Figures 1 and 2]. The measurement at the L₂₋₃ interspace was taken perpendicular to the long axis of the vertebral body. All of the measurements were taken by two of the authors independent of each other and were verified by a co-author. The authors reviewed any discrepancy between the measurements. The investigators were blinded to the age of the patients. The SED at T₆₋₇ and T₉₋₁₀ levels (straight and inclined) and the SED at L₂₋₃ (straight) were determined and compared using repeated measures of ANOVA and two-tailed paired *t*-tests. A Bonferroni correction for 10 pairwise comparisons was applied, such that *P* < 0.005 was considered statistically significant. Data analysis was performed in Stata/IC 14.2 (College Station, TX: StataCorp, LP).

Results

The study cohort included 108 children (51.4 ± 19.3 months of age). The height and weight of the cohort were 101.4 ± 12.9 cm and 16.3 ± 4.5 kg, respectively. The inclined SED was 21.6 ± 4.9 mm at T₆-T₇ and 20.5 ± 4.7 mm at T₉-T₁₀. The straight SED was 18.2 ± 3.9 mm at T₆-T₇, 18.3 ± 4.1 mm at T₉-T₁₀, and 21.8 ± 5.6 mm at L₂-L₃ [Table 1]. Statistical analysis revealed significant variability in the SED (*P* < 0.001) when comparing the 5 measurements. Pairwise comparisons among the measurements are summarized in Table 2. The straight SED at T₉-T₁₀ was significantly shorter than the other four measurements.

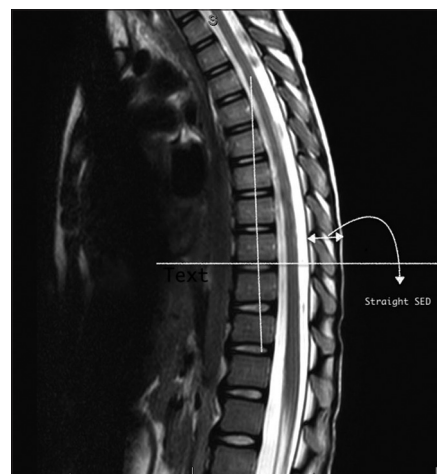


Figure 1: Magnetic resonance image showing the technique to measure the straight skin-to-epidural depth at the upper thoracic region (T₆₋₇)

Table 1: Skin-to-epidural distance at the various vertebral levels

Level	Straight distance			Inclined distance		
	Mean±SD	Median, Range	IQR, 95%CI	Mean±SD	Median, Range	IQR, 95%CI
T ₆₋₇	18.2±3.9	18.2 (9.4-35.9)	3.5 (18.1-19.7)	21.6±4.9 mm	20.8 (11.4-42.9)	5.2 (20.7-22.5)
T ₉₋₁₀	18.3±4.1	17.7 (10.3-32.9)	4.3 (17.6-19.1)	20.5±4.7 mm	20.5 (10.9-41.5)	4.7 (19.6-21.4)
L ₂₋₃	21.8±5.6	20.9 (8.6-43.5)	5.8 (20.8-22.9)	-	-	-

All distances are listed in mm. SD=Standard deviation; IQR=Interquartile range; CI=Confidence intervals

Table 2: Pairwise comparisons of the SED at various levels and angles

Levels and angle	The pairwise difference in SED (95% CI of difference) and P ^a			
	(1)	(2)	(3)	(4)
(1) T ₆₋₇ inclined				
(2) T ₆₋₇ straight	2.7, (2.3, 3.1), P<0.001			
(3) T ₉₋₁₀ inclined	1.1, (0.6, 1.6), P<0.001	-1.6, (-2.1, -1.1), P<0.001		
(4) T ₉₋₁₀ straight	3.3, (2.8, 3.7), P<0.001	0.5, (0.2, 0.9), P=0.002	2.2, (1.9, 2.5), P<0.001	
(5) L ₂₋₃ straight	-0.2, (-0.9, 0.4), P=0.473	-3.0, (-3.7, -2.2), P<0.001	-1.3, (-2.0, -0.7), P<0.001	-3.5, (-4.1, -2.8), P<0.001

^aP by paired t-test; P<0.005 considered statistically significant after Bonferroni correction for 10 simultaneous comparisons (P<0.005/10=P<0.05). CI=Confidence interval, SED=Skin-to-epidural distance.



Figure 2: Magnetic resonance image showing the technique to measure the inclined skin-to-epidural depth at the upper thoracic region (T₆₋₇)

Discussion

The depth of epidural space from the skin has been shown to vary by site, vertebral level, patient characteristics including age and weight, and the angle of the puncture.^[16] Previous studies have endeavored to calculate the SED using various techniques in children. There have been two previous studies based on MR imaging, measuring the SED in children. Franklin *et al.* measured the SED at the lumbar level (L₃₋₄) while Wani *et al.* measured the SED at two thoracic levels (T₆₋₇ and T₉₋₁₀), devising a mathematical formula to estimate the SED.^[10,11] Several authors have estimated the SED in children using direct measurement of the depth of needle insertion during epidural anesthesia.^[4-6] Uemura *et al.* measured the SED at the L₃₋₄ level in 355 pediatric patients using needle marks and defined the relationship between the distance and body weight as $D = (W + 10)$

times 0.8 mm.^[4] Although Dalens *et al.* directly measured and reported the SED at the lumbar and thoracic vertebral levels, they did not provide a formula for estimating the distances.^[6] Kosaka *et al.* reported that the distance between the skin and the epidural space increased according to age and body weight.^[17] Bonadio *et al.* reported that the highest correlation was reported between the depth of the lumbar puncture and body surface area.^[5]

Using MR imaging, the present study determined and compared the SED at two thoracic levels using straight and inclined measures and one straight measure at the lumbar level (the lumbar vertebrae and the space being more perpendicular to the skin). We noted that the SED was not constant throughout these levels of the vertebral column. It is greatest at the lumbar level and shallowest at the T₉₋₁₀ level. Similar results were reported in adults with the shallowest depth at the lower thoracic levels.^[16] Several formulas to estimate the SED have been previously reported in the literature.^[4-5,8-10] However, these studies are generally limited to a single vertebral level. Given the variation noted in the measurements at the 3 vertebral levels in the current study, we do not believe that a single mathematical formula, whether based on height, weight, or age, is likely to be accurate in calculating the SED at all vertebral levels. Furthermore, the SED varies based on the trajectory of the needle. This may be particularly relevant at the thoracic level where the angle with which the needle contacts the skin may be more acute (inclined). Our current measurements show that a change in the trajectory of the needle from straight to inclined may change the SED by as much as 2–3 mm.

Knowing the approximate SED may facilitate the performance of epidural anesthesia and catheter

placement with the potential to limit trauma, dural puncture, or the need for repeated attempts at different interspaces. In younger children, the combination of the shallow depth of the epidural space with wide interpatient variability indicates that vigilance is required during insertion of epidural needles in small children. Although the clinical experience has demonstrated the safety of direct placement of an epidural catheter at both the lumbar and thoracic level, complications may occur including inadvertent entry into the intrathecal space and rarely neurologic damage.^[18]

A limitation of the current study is that all of the patients were studied in the supine position whereas epidural analgesia and/or catheter placement may be performed in either the sitting or lateral decubitus position. Till date, there are limited data regarding changes in the SED with changes in position. The SED did not change when measured using MRI in the flexed and neutral positions in a study of 10 young, healthy female volunteers.^[19] However, any variation in SED related to positioning would introduce further error if using a single formula to estimate this distance.

The variable SED depth at the lumbar and thoracic areas may limit the accuracy of a single formula in calculating the SED using in the pediatric population as we have noted in the current study, significant variations based on the vertebral level as well as the needle insertion plane (straight or included). There is also significant interpatient variability at each vertebral level as demonstrated by the range of values noted. Even small variations in the approximated SED could lead to potential complications or difficulties with accessing the epidural space. The potential variation in SED related to positioning may introduce further error if using a single formula to estimate this distance. These data provide additional information regarding the variability of the SED in the pediatric-aged patient and further question the applicability of a single formula. Additional work is needed to compare the derived and the actual SED measurements, which can only be achieved during epidural catheter placement.

Ethics

The study was approved by the Institutional Review Board at King Fahad Medical City.

Acknowledgments

This study includes patient data and measurements that were used in two previously published manuscripts (Wani TM *et al.* Estimation of the depth of the thoracic epidural space in children using magnetic resonance imaging. *J Pain Res* 2017;10:757-762 and Wani T *et al.* Dura to spinal cord

distance at different vertebral levels in children and its implications on epidural analgesia: A retrospective MRI-based study. *Pediatr Anesth* 2018;28:338-341).

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Conflicts of interest

There are no conflicts of interest.

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