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Comparison of the Skin-to-Epidural space Distance at the three Thoracic levels In Children using Magnetic Resonance Imaging for Epidural Anesthesia

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ABSTRACT

Background: Several ways were used to assess the distance from the skin to the epidural space, with the aim of increasing the success of the technique. MRI is the most significant technological advancement in the diagnostic examination of the pediatric spine. The aim of this study was to evaluate the distance between the skin and the epidural space through MRI at three thoracic segments in children aged 0 to 13 years.

Methods: Retrospective study with 105 children aged 0 to 13 years in the supine position underwent MRI, and the 2nd, 5th, and 10th thoracic segments were measured. The following parameters were evaluated: skin and the epidural space; needle entry angle between the skin and intervertebral space; and distance corrected by an angle between skin and the epidural space. To compare the proposed data between the samples, we used the Kruskal-Wallis test. The Kruskal-Wallis rank test is a non-parametric method for testing whether samples come from the same distribution.

Results: This study evaluated 60 male and 45 female children. The mean distance between Skin-EpiS was 29.27 mm at T2, 26.52 mm at T5, and 24.28 mm at T10, with a significant difference, being the greatest distance found in T2. The Skin-EpiS at T10 was shorter than the other two measurements. Regarding needle entry angle between skin and the three intervertebral spaces, the smallest angle was observed (T2=27.16°) significantly smaller than in the other two spaces (T5=38.68°, T10=39.08°). However, this difference in angle did not result in a significant difference in the distance between the skin and epidural space corrected by the entry angle in the three intervertebral spaces, being practically the same, T2=33.0 mm, T5=34.60 mm, T10=32.1 mm.

Conclusion: Precise Skin-EpiS distance information can facilitate accurate needle placement in children's epidural space and thus decrease the risk of complications. This study in children aged 0 to 13 years provided important information for performing single shots or continuous thoracic epidurals, reducing the potential for complications during its performance.

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Key Points

•Question: A retrospectively investigated the distance from the skin and epidural space (Skin-EpiS), the angle of entry of the needle between the skin and the intervertebral space (A°), and the angle-corrected distance between skin and epidural space (Dc-A-EpiS) in the three thoracic segments (T2, T5, T10), analyzing the MRI of children aged 0 to 13 years, without spinal or spinal cord disease, were studied to explain the lack of injury during drilling of the thoracic epidural and possibility of performing thoracic

spinal anesthesia in children.

• **Findings:** The mean dura mater to spinal cord distance was 29.27 mm at T2, 26.52 mm at T5, and 24.28 mm at T10, and the mean distance corrected by angle skin and epidural space was 33.00 mm at T2, 34.60 mm at T5, and 32.10 mm at T10.

• **Meaning:** The correction for the angle of entry of the needle into the intervertebral space significantly increased the distance between the skin and epidural space, being the greatest distance in T2 and the smallest distance in T10.

Introduction

Epidural anesthesia and analgesia in children can be performed in the thoracic, lumbar or caudal region in a single shot or continuously with a catheter. Technical difficulties encountered in the execution epidural anesthesia in children include smaller anatomical structures landmarks and shallower distances from the skin to the epidural space [1]. Prediction of the approximate distance from the skin to the epidural space with ultrasound (US) may provide useful information to increase the safety and success in obstetrics, spinal anesthesia, and prediction of technical difficulties [2-4].

The determination of the distance between the skin and the epidural space was performed after access with loss of resistance, US for caudal epidural, with computerized tomography (CT), US in infants and small children, and small children, magnetic resonance imaging (MRI), and termination of the normal conus medullaris in children with MRI [9].

Recently, our group evaluated several distances between the skin and the spinal cord in children from 0 to 13 years old, mainly showing a large space between the dura mater and the spinal cord, allowing entry of a spinal anesthesia needle or accidental perforation of the dura mater during an epidural, justifying the non-occurrence of neurological injury, and the possibility of performing single shot thoracic spinal anesthesia in children for laparoscopic cholecystectomy and adults patients [10-12].

The aim of this study was to evaluate the distance from the skin to the epidural space (Skin-EpiS) in three different thoracic segments, with the aim of performing an epidural in children, correlating with the needle entry angle, to verify whether or not there is an increase in the path that the epidural needle will travel.

Methods

A retrospective study approved by the Ethics and Research Committee under number 0867/2009 for the evaluation of the thoracic and lumbar spine by MRI in adults and extended to children between 0 and 13 years old. As this is a retrospective study, the waiver of the Free and Informed Consent Form was requested and approved. The cohort for the current study included data and MRI from children who had been included in published evaluating the distance between the dura mater and the spinal cord [10].

Between April 1, 2019, to June 30, 2022, selected evaluate the MRI performed at the Cancer Hospital (HC 1) of the National Cancer Institute (INCA), and the MRI was evaluated in the database of the Department of Radiology. All healthy children were examined supine with the MRI 1.5-T superconducting system scanner (Gyroscan Intera, Philips Medical Systems, Best, the Netherlands) or Magneto Symphony 1.5-T Siemens. Each MRI exam complied with the protocol established by the radiology service and evaluated patients with different clinical conditions. The results obtained were stored in a digital imaging system.

The inclusion criteria for this research were child patients of both sexes, aged between 0 and 13 years, who did not present any pathology of the cervical, thoracic, and lumbar spine and/or spinal cord. Children's demographic data were recorded as gender and age.

The images of the thoracic spine were performed using the Spin-Echo sagittal slice. In one of the MRI images of a studied patient, with the spinous apophyses and the studied evaluations (Figure 1) that covered the entire spine (C1 to L5), the relationships between the spinal cord and the vertebrae in the interspinous spaces of T2, T5, and T10 were evaluated. The measurements were evaluated in the 2nd, 5th, and 10th thoracic vertebral segments. In the three thoracic intervertebral spaces, the distance from the skin to the epidural space (Skin-EpiS), the needle entry angle between skin and intervertebral space (Angle-Degree), in a horizontal position perpendicular to the spine was measured. Each space was measured three times and the mean value between these measurements was calculated. In all patients, the needle entry angle necessary to reach the subarachnoid space in the interspinous spaces of T2-T3, T5-T6 and T9-T10 was measured, using the protractor tool available in the Carestream PACs image viewer. After obtaining the angles for entry of the spinal needles into the three spaces, the distance between the skin and the epidural space was again calculated, correcting the angle of entry of the needle into the intervertebral space and obtaining its measurement (DcA-Skin-EpiS). Each space was measured again three times and the mean value was calculated.

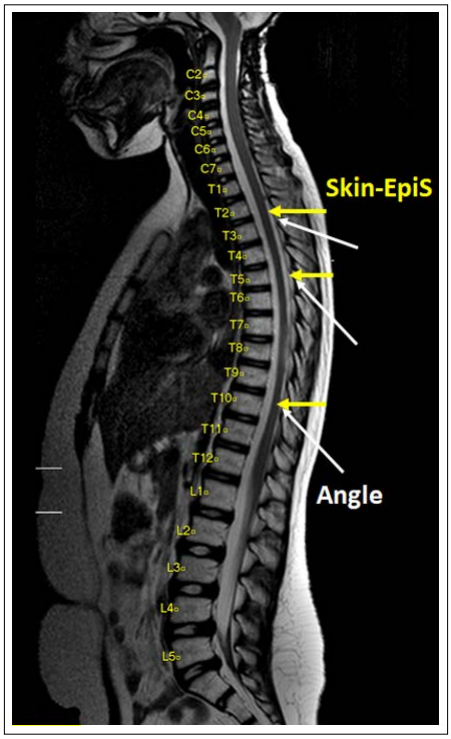

Figure 1: Evaluation of the distance between the skin epidural space (Skin-EpiS)

Statistical Analysis

To compare the proposed data between the samples, we used the Kruskal-Wallis test. The Kruskal-Wallis rank test is a non-parametric method for testing whether samples come from the same distribution.

Results

In the period from April 1, 2019, to June 30, 2022, 21,392 MRIs were performed at the hospital. Using patients born between April 1, 2006, and June 30, 2022, we found 3,055 MRIs. Using the following terms as filters: dorsal column, thoracic column, total column, spinal cord compression, and neuroaxis 252 MRI exams were selected for the research. MRI exams that presented the following terms were excluded: intradural, intramedullary, or extramedullary lesions; and/or extradural injuries with spinal cord compression; and/or exams where the skin has been cut in the image; and/or patients over 13 years of age; and/or exams of the same patient, resulting in 105 selected exams (Figure 2). In the study was retrospectively evaluated, with 60 male and 45 female children. Children's demographics are shown in Table 1.

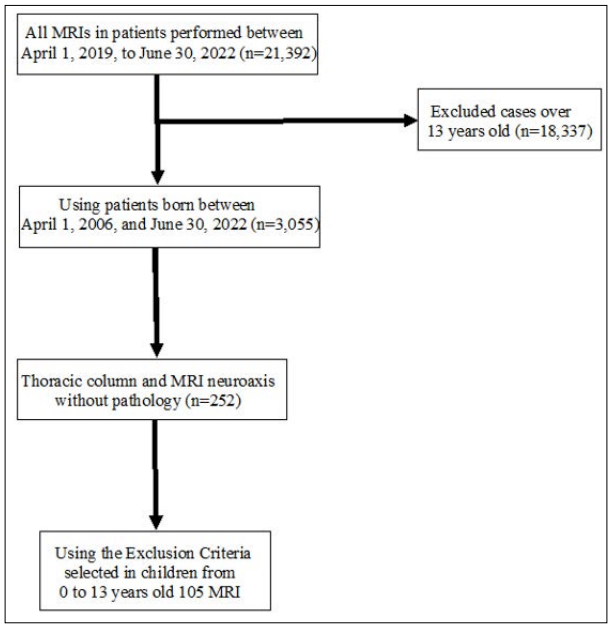

Figure 2: Consort Flow Diagram

Table 1: Patients' characteristics regarding age, weight, height, and sex (Mean±SD)

Variable	Children
Number	105
Age (years)	7.03±3.32
Weight (kg)	26.23±14.02
Height (cm)	119.77±22.92
Gender: F / M	45 / 60

MRI results of a patient with all measurements evaluated in the three segments and the increase calculated by the entry angle of a needle (Figure 3, Figure 4). This study revealed a clear correlation between weight and skin-to-epidural distance in children (Spearman correlation is 0.55).

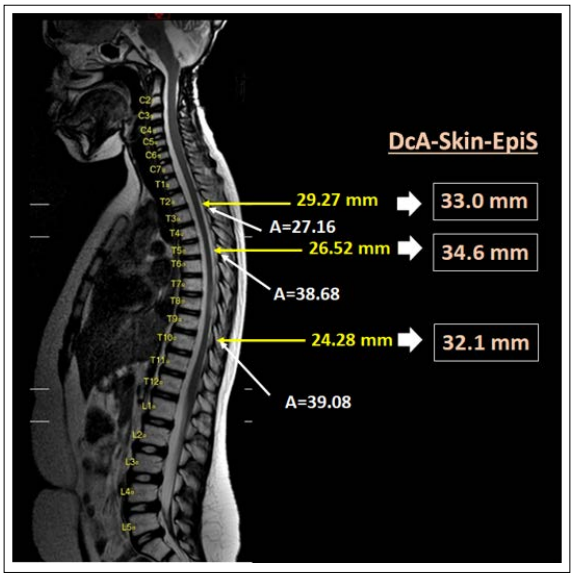

Figure 3: Results of measurements in the three thoracic segments the distance between the skin and epidural space, and corrections by angle

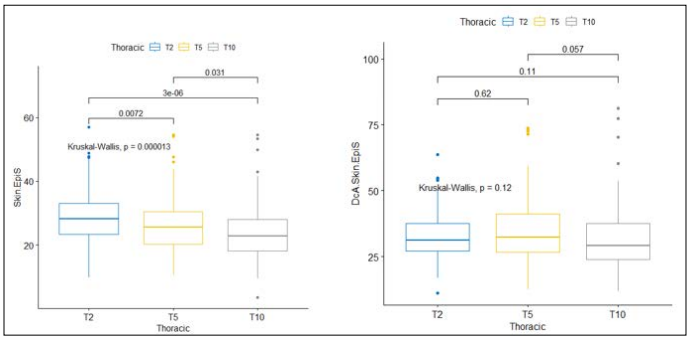

Figure 4: Boxplot of measurements in the three thoracic segments the distance between the skin and epidural space, and corrections by angle

The mean distance between skin to the epidural space (Skin-EpiS) was 29.27 mm at T2, 26.52 mm at T5, and 24.28 mm at T10, with a significant difference, being the greatest distance found in T2 (Table 2). The Skin-EpiS at T10 was shorter than the other two measurements (Figure 4).

Regarding needle entry angle between skin and the three intervertebral spaces, the smallest angle was observed (T2=27.16º) significantly smaller than in the other two spaces (T5=38.68º, T10=39.08º) (Figure 5). However, this difference in angle did not result in a significant difference in the distance between the skin and epidural space corrected by the entry angle in the three intervertebral spaces, being practically the same, T2=33.0 mm, T5=34.60 mm, T10=32.1 mm (Table 2).

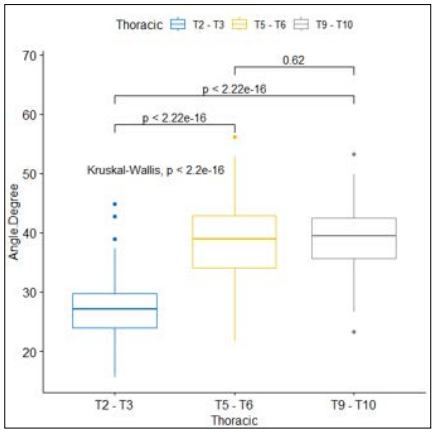

Figure 5: Needle entry angle in the intervertebral space of the three thoracic segments

Table 2: Minimum, mean (standard deviation), and maximum, in millimeters, skin to epidural space, angle entry of needle, and distance corrected by angle in all 105 children

Variable (0 – 13 Years)	2nd Thoracic			5th Thoracic			10th Thoracic		
	min.	mean	max.	min.	mean	max.	min.	Mean	max.
Skin-EpiS	15.80	29.27±8.20	57.00	14.90	26.52±8.36	54.50	11.9	24.28±8.75	54.60
Angle-Degree (º)	15.60	27.16±5.12	44.90	21.70	38.68±6.10	56.20	23.3	39.08±5.23	53.30
DcA-Skin-EpiS	11.00	33.00±9.20	63.70	12.40	34.60±12.0	73.80	11.8	32.10±12.5	81.3

Discussion

Thoracic epidural placement in infants and young children can be a technique to be used, which is why it is essential to know the anatomy and the distances between the skin and the epidural space. In this study with children aged 0 to 13 years, the smallest mean distance between the skin and the epidural space was found at T10 (24.28 mm), compared with T2 (29.27 mm) and T5 (26.52 mm), with a mean of 26.69 mm. The needle entry angle in the intervertebral space was smaller in T2 (27.16º), compared with the same angle in T5 (38.68º), and T10 (39.08º). Correcting the needle entry by these angles resulted in practically the same distance in the three intervertebral spaces around 33 mm, resulting in a 22% increase in the Skin-EpiS distance.

In pediatric epidural anesthesia, the distance from the skin to the epidural space is of special importance because of the great differences in size of the patients, newborns, children, and adolescents. The skin-to-epidural distance can vary considerably between children, depending on a multitude of factors, such as age, weight, and body weight. Approximate distance prediction from the skin to the epidural space with various techniques can provide useful information to increase safety and success in the approach of the epidural space single shot or with catheter [2-4].

In 1988, studying 158 children of different ages (mean age, 22 months), a correlation was found between the depth of the lumbar epidural space and the body surface, through linear regression [13]. Later in 1992, the evaluation of the distance from the skin to the lumbar epidural space (L3-L4) in 355 pediatric patients, using a formula showed a good correlation between the distance to the epidural space and body weight [14]. An article with 29 patients with the aim of predicting the depth of the epidural space using CT scan Pythagorean triangle trigonometry, indicates that use of a CT-derived distance from the skin to the epidural space may provide a useful tool for an anesthetist to predict the actual epidural needle insertion distance prior to insertion [7]. Our study was performed with MRI as it is considered to be the most significant technological advancement in the diagnostic examination of the spine.

In a study with 108 children aged 3 months to 8 years, using MRI at spaces T6-T7, T9-T10, and L2-L3, in the supine position the distance from the skin to the epidural space was evaluated, the mean obtained was 18.2 mm, 18.3 mm, 21.8 mm, respectively [1]. These results were slightly lower than those obtained in our study's children aged 0 to 13 years, with an average Skin-EpiS distance of 26.69 mm between the three thoracic spaces, which corrected for the intervertebral entry angle resulted in a mean of 33 mm.

A sagittal view of MRI images of 109 children, ranging in age from 1 month to 8 years, without spine pathology, at two thoracic levels showed that the depth of the pediatric thoracic epidural space has a stronger correlation with weight than with age or height [15]. Different from this correlation found, our study did not perform the correlation with age and height and the Skin-EpiS distance in practically the same number of children.

From the study with 70 children with normal lumbar spine MRI, a formula was presented that is more predictive of the distance between the skin and the epidural space in younger children than previously published formulae derived from direct needle measurement [16].

In a recent study with 616 pediatric patients evaluating the skin-epidural distance in the thoracic (n=225) and lumbar region (n=363), performed via the midline approach, to determine the relationship between age, weight and ethnicity, and depth of the epidural space, it was observed that the best correlation was

demonstrated between skin-to-lumbar epidural distance and body weight (R2 = 0.729) [17].

Knowing the distance from the skin to the epidural space so that needle entry is avoided may prevent such issues. Needle for pediatric epidural anesthesia, 18 G, 20 G, 22 G Tuohy bevel, with metallic stylet, transparent barrel, graduations every 50 mm (Figure 6). This graduation allows the insertion of the needle with precision. Our study revealed a clear correlation between weight and skin-to-epidural distance in children. This correlation has been noted in several studies [5,14,17].

Conclusion

Approximate distance prediction from the skin to the epidural space with various techniques can provide useful information to increase safety and success in the approach of the epidural space single shot or with a catheter [2-4,13,14]. Differences in the depth of epidural space can have profound implications on the children, such as inadvertent dural punctures, complications related to epidural catheter insertion, and neurological injury.

The smaller Skin-EpiS at lower thoracic intervertebral spaces observed in the study with derived a formula for estimation of this distance and MRI is similar to our findings with children without spinal disease [5,15].

To our knowledge, this is the first study using MRI to evaluate the Skin-EpiS at the three thoracic levels in the pediatric population. Precise Skin-EpiS distance information can facilitate accurate needle placement in children's epidural space and thus decrease the risk of complications. This MRI study of the thoracic region was always performed in the supine position, while the approach to the epidural space through a single shot or catheter placement in the lumbar and thoracic region can be performed on the child in the lateral decubitus or sitting position. This can generate a difference in the depth of the epidural space in children aged 0 to 13 years. This study in children aged 0 to 13 years provided important information for performing single shots or continuous thoracic epidurals, reducing the potential for complications during its performance.

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Conflict of Interest

No

Contribution

No

IRB

No

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