

Retrospective Review



A Morphometric Study Analyzing the Anterior Epidural Space Volume Throughout Childhood

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Background: Following disc herniations, fragments migrate into the anterior epidural space within the lumbar spine. Although the volume of this area has been previously described in the adult population, the volume is relatively unknown within children.

Objectives: Investigate the relative volume in the lumbar anterior epidural space within the growing spine by using imaging studies.

Study Design: Retrospective chart review.

Setting: University Medical Center in Lubbock Texas. A teaching hospital affiliated with Texas Tech University Health Sciences Center.

Methods: We conducted a retrospective review of the charts of pediatric patients seen at our institution from 2018 through 2020. Charts chosen for our investigation contained computed tomography imaging of the lumbar spine, showing no deformities. Thirty patients were stratified equally among 3 age groups, 2-5 years old, 10-12 years old, and 16-18 years old. The anterior epidural space was measured in each patient 3 times using the previously reported method used by Teske et al (1). Results were compared with a combination of analysis of variance (ANOVA) and single tail paired t test.

Results: There was a statistically significant difference in the anterior epidural space size among age groups at all levels of the lumbar spine. When comparing only 2 groups together, the younger age group had anterior epidural space sizes significantly smaller than the other age group for all levels of the lumbar spine. The 10-12 age group had a significantly smaller space in the anterior epidural space than the 16-18-year olds only at the level of L2, L4, and L5 ($P = 0.048, 0.039$, and 0.031 , respectively). Within the 16-18-year age group, the anterior epidural space was significantly different between L4 and L3 and L2 and L3 ($P < 0.001$ and $P = 0.019$, respectively).

Limitations: Our study is limited by its retrospective nature and the sample size of the patient groups. Furthermore, the use of computed tomography imaging and not making physical measurements limits our accuracy.

Conclusion: The volume of the anterior epidural space is smaller in the pediatric population than the adult population. The inability of herniated discs to fit within the epidural space in children and adolescents could potentially be the cause of the increased failure of conservative treatment for pediatric lumbar disc herniations.

Key words: Anterior epidural space, lumbar herniated disc, low back pain, fossa corporis vertebralis dorsalis, free disc fragment, lumbar spine anatomy

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It is known that low back pain is common in the adult population and is commonly secondary to lumbar disc herniation and degenerative changes (1). An estimated 40% of adults will experience a herniated

disc at some point in their life (2,3). Pediatric patients, however, experience back pain and disc herniation to a lesser degree with only 0.1% - 0.2% of them hospitalized for a lumbar disc herniation (3). Compared to adults,

pediatric patients are more likely to present with acute back pain due to disc herniation following trauma or exercise related injury (3,4). Pediatric herniated discs secondary to trauma are seen in 30%-60% of herniated discs in that population, whereas, in adults, herniated discs are more commonly spontaneous and related to degenerative changes in the spine (3).

Along the posterior aspect of the lumbar vertebra is an area termed the anterior epidural space, or “fossa corporis vertebralis dorsalis” (1). This space is anterior to the epidural sac within the lumbar concavity. The posterior longitudinal ligament is attached to the posterior vertebra via a midline septum. This septum also serves to separate the anterior epidural space into 2 compartments, a left and a right. Moving laterally from the posterior longitudinal ligament, the anterior epidural space is limited posteriorly by the highly vascular peridural membrane (1,5-8).

Following lumbar disc herniation, disc fragments can migrate either superiorly (42%) or inferiorly (40%), and sequester either on the right or the left (94%), rarely straddling the midline (1,5). The smaller fragments in this space can remain asymptomatic and undergo resorption; larger fragments may still put pressure on the thecal sac or spinal cord.

Although the anterior epidural space volume has been explored in the adult population by Teske et al (1), little is known about the volume in pediatric patients. In the pediatric population the spine is still developing and maturing, so the volume may change as the child ages. We sought to measure the anterior epidural space volume across 3 age ranges in pediatric patients.

METHODS

This is a retrospective review conducted at a single institution from 2018 through 2020. Thirty patients were randomly selected for the investigation. They were stratified equally by age range with 10 in the 2-5 year range, 10 in the 10-12 year range, and 10 in the 16-18 year range. Patients were included if they had computed tomography (CT) imaging of their lumbar spine that showed no deformities. Patients were excluded if they had previous spinal surgery or spinal disease.

The patient images were examined utilizing the measurement software within the electronic medical record (Cerner SkyVue Distribution version 4.9.4 Cerner Corporation). The compartments and total volume of the anterior epidural space were measured using a similar technique to Teske et al (1) that had been adapted from Larsen et al (9,10).

The distance between the superior and inferior end plate were measured on the dorsal plane to recreate the sagittal space. The largest lateral depth of this space was subsequently measured (Fig. 1). Finally, the areas to each pedicle were measured from the center of the vertebra and combined with the aforementioned measurements to yield the final volume of the anterior epidural space. Each measurement was repeated 3 times and the measurements were then averaged for the final values.

Anterior epidural space values were first measured with an analysis of variance (ANOVA) among all 3 age groups. Paired, single-tailed t tests were then utilized to measure the difference between individual groups as well as group specific size characteristics. Qualitative characteristics were compared using χ^2 tests. All statistical calculations were done in RStudio 4.2.3 (The R Foundation).

RESULTS

The anterior epidural space volumes were significantly different among the 3 age groups (Table 1).

Ten patients from each of the age groups were included in the study. The average age of the patients was 4 years, 10.9 years, and 17.2 years, respectively. The 2-5-year-old age group had 4 (40%) boys; the average volume of both genders' anterior epidural space was: L1, 0.023 mL; L2, 0.025 mL; L3, 0.044 mL; L4, 0.048 mL; and L5, 0.073 mL. The 10-12-year-old group had 6 (60%) boys; the average volume of both genders' anterior epidural space was: L1, 0.090 mL; L2, 0.115 mL; L3, 0.144 mL; L4, 0.162 mL; and L5, 0.201 mL. Finally, the 16-18-year-old age group had 6 (60%) boys; the average volume of both genders' anterior epidural space was: L1, 0.111 mL; L2, 0.143 mL; L3, 0.157 mL; L4, 0.240 mL; and L5, 0.290 mL.

When comparing only 2 groups together, the younger age group had anterior epidural space sizes significantly smaller than the comparative age group at all lumbar spine levels. The 10-12 age group had significantly smaller volumes in the anterior epidural space than 16-18-year olds, but only at L2, L4, and L5 ($P = 0.048$, $P = 0.039$, and $P = 0.031$, respectively).

Within the 16-18-year age group, the anterior epidural space was significantly different between L4 and L3 and L2 and L3 ($P < 0.001$ and $P = 0.019$, respectively). There were no differences between the sizes at levels L5 and L4 or L3 and L2. In the 10-12 age group, lumbar vertebra levels L2 and L1 had significantly different anterior epidural space sizes ($P = 0.01$); however,

there were no differences between levels L5 and L4, L4 and L3, or L3 and L2. Unlike the aforementioned age groups, the 2-5 age group did not have any significant differences between any lumbar vertebrae.

DISCUSSION

As pediatric patients grow and their spine continues to mature, the space within the anterior epidural space also grows. The patients presented in this morphometric study had less volume in their anterior epidural spaces than was previously demonstrated by Teske et al (1). Their study measured the anterior epidural space in cadaveric spines through use of both CT imaging and a resin injected within the space itself. When utilizing the CT imaging, they found the sizes of the anterior epidural space to be: L3, 0.57 mL; L4, 0.68 mL; and L5, 0.66 mL (1).

Our patients had a notably smaller anterior epidural space volume, which we attribute to the differing maturity level of the spines being measured. Though age was not noted within Teske et al's study (1), the use of cadaveric spines indicates that the study subjects were older than our patients (1). Degeneration of the vertebral body likely led to a larger degree of inward curvature of the spine allowing for a greater space than in the healthy spines of children (11). Furthermore, the spine does not completely stop growing until around the age of 18, indicating that our age groups of 2-5 and 10-12 were still growing, which is the reason for the smaller volume when compared to the 16-18 year olds' volume (12,13).

The size difference between the anterior epidural space within our patients can be attributed to their spinal maturity and the growth phase they are in. The growth of the spine occurs in 3 distinct phases. The first phase is in newborns and occurs until the age of 5 and is characterized by rapid growth. At the end of these 5 years, the spine will be more than 50% of its final length (13,14). The second phase occurs between the years of 5-10 and is characterized by a slower growth pattern, with growth during these years at only 2.5 cm per year (13,14). Finally, the last phase occurs after age 10 during puberty. This phase is characterized by rapid growth. The ages of these phases are not exact and variations of up to 4 years is common (13).

Our pediatric population captures patients within each growth phase and explains the difference within their relative sizes. The rapid and expansive growth within the first 5 years of life explains why the patients in our youngest age group varied greatly from the

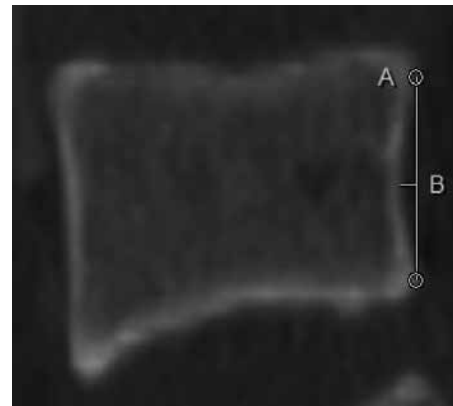


Fig. 1. Computed tomography image of an 18-year-old's L4 vertebra in the midsagittal plane. The lines indicate the distance measurements taken in the sagittal plane similar to as previously described (1,9,10).

Table 1. Lumbar epidural space volumes across all age ranges. Volumes expressed in mL.

Vertebral Level	Age 1-3 (SD)	Age 10-12 (SD)	Age 16-18 (SD)	P Value
L1	0.024 (0.018)	0.090 (0.035)	0.110 (0.036)	< 0.001
L2	0.025 (0.013)	0.115 (0.028)	0.143 (0.043)	< 0.001
L3	0.044 (0.023)	0.144 (0.036)	0.157 (0.080)	0.002
L4	0.048 (0.028)	0.162 (0.056)	0.241 (0.093)	< 0.001
L5	0.073 (0.018)	0.201 (0.085)	0.290 (0.065)	< 0.001

older age groups. Following the first phase, growth of the spine slows and the lumbar spine is 90% of its total height by the end of year 10 (14). Despite this, there was still enough growth between the 10 and 18 years of age that our 10-12 and 16-18-year age groups had significantly different anterior epidural space volumes at L5, L4, and L2. Moreover, our patients within the 16-18-year age group represent the deceleration part of the final phase of spine growth, meaning their spines can be considered reflective of a healthy adult (12,13). The volume of their anterior epidural space may be a more accurate prediction for young, healthy adults with lumbar vertebral disc herniations compared to the volumes measured by Teske et al (1).

Following the acute and painful phase of lumbar disc herniation, the anterior epidural space can sequester migrating lumbar disc fragments (15,16). Before

entering the anterior epidural space, the disc can apply pressure to the nerve roots and the thecal sac. The retrovertebral anterior epidural space is an area to which the disc can migrate such that it no longer applies pressure to the surrounding neural structures (5,8). Furthermore, once a disc is sequestered to the anterior epidural space, if the patient remains symptomatic, this is a sign that there are other fragments elsewhere that are problematic (8).

The average lumbar herniated disc has a volume of 0.49 mL in the initial painful phase, but decreases to 0.21 mL shortly thereafter during the remission period (16). This indicates that, using the volumes derived from Teske et al (1) for the adult population, the lumbar discs can migrate into the anterior epidural spaces above or below and become asymptomatic (1,16). This is known to happen in conservatively managed cases, as well as surgically managed cases in which remaining disc fragments migrate superiorly or inferiorly to reside within the anterior epidural space.

The consensus is to leave these migrated fragments in place as long as they remain asymptomatic and difficult to reach, since inadvertent damage in the area can lead to heavy bleeding from the venous plexus on the peridural membrane (1,17). The average volume noted by Kawaji et al (16) of herniated discs is too big to migrate into the anterior epidural space of pediatric patients, based on our measurements, during the initial painful phase (16). During the remission period, if a disc herniation is slightly smaller than the reported average, there may be space for it to migrate into the anterior epidural space of older pediatric patients.

Pediatric lumbar disc herniation is rare, especially in children younger than 10 (4). This is likely due to histopathologic disc degenerative changes starting around the age of 11 (18). Despite this, pediatric lumbar disc herniation remains a rare condition and commonly is secondary to a traumatic or sports injury (3,4). Due to its relative rarity, it is commonly misdiagnosed or there is a delay in diagnosis when compared to adult patients (4,19).

There is also a difference in treatment success rates between adults and children. In studies with adult patients, residual pain during the 6–12-month period was similar in surgical and conservative treatment groups (4). Furthermore, in the conservative group, more than

90% of patients had a decrease in the herniated disc's size secondary to disc resorption (2). Within the pediatric population, even though surgical intervention is not the first-line treatment, surgical intervention is commonly required as pediatric patients mostly fail conservative management (3,4). This is at least partially due to the decreased resorption of the disc fragments (3). This can possibly be explained by the smaller disc fragment volume in the anterior epidural space in pediatric patients. Disc fragments in adults can readily fit in this space and undergo resorption due to high vascularity. However, in pediatric patients, the space is too small to allow most disc fragments to reside, especially during the initial painful phase (1,16). This leaves more disc material in the canal and surrounding area, effectively decreasing the spinal canal size. A study by Linkoaho et al (20) demonstrated that adolescent patients with a decreased area in their spinal canals were more likely to require surgery. Therefore, small anterior epidural space volumes, coupled with slower resorption rates in pediatric patients, may contribute to the increased need for surgery in the pediatric population when compared to adults.

Limitations

A limitation of this study is that it is retrospective. Furthermore, all measurements were made using CT imaging. Although CT is ideal for looking at bony structures, it has low contrast resolution, which may limit precision while taking measurements. CT also makes looking at surrounding soft tissue structures difficult. Furthermore, ideal measurements would be taken from cadaveric spines, but this is not feasible with the age groups included. The study is also limited by the sample size of 30 patients.

CONCLUSION

The anterior epidural space volume in pediatric patients is smaller than in the adult population. The decreased ability of fragmented disc herniations to fit in this space could contribute in part to why pediatric herniated discs commonly require surgery. More research is needed to fully elucidate the relationships between pediatric herniated discs and the anterior epidural space and the reason for the increased failure of conservative management.

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