Original Clinical Article

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Spinal canal dimensions affect outcome of adolescent disc herniation

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Abstract

Purpose Small spinal canal dimensions play a role in symptomatic adult disc herniation, but its role in adolescent disc herniation has not been investigated with MRI. The goal of this study was to examine retrospectively if there is a correlation with dimensions of osseous spinal canal and need of discectomy in an adolescent population suffering from disc herniation.

Methods A retrospective review of child and adolescent patients who were treated in our institution for back or back-related leg pain was conducted. Patients were divided in three groups; group 1: lumbar disc herniation requiring operative treatment; group 2: lumbar disc herniation treated with observation; and group 3: back pain and no disc herniation on MRI. MRI images and radiographs were studied for spinal canal dimensions and compared between groups.

Results The discectomy group presented considerably smaller spinal canal dimensions measured from the MRI images than the two other groups.

Conclusion Adolescent patients requiring operative treatment for symptomatic disc herniation have smaller osseous spinal canals than patients who are managed non-operatively.

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Disc herniation is infrequent in adolescents. The exact prevalence remains unknown due to the small number of patients with disc herniation in adolescent low back pain (LBP) studies. These studies present a prevalence of disc herniation between 2% and 3%.[1,2] Trauma precedes approximately two-thirds of these cases, whereas disc degeneration and degenerative herniation are not as common as in adults.[3-5] Failure of conservative treatment in adolescent disc herniation necessitates operative intervention more often compared with adult degenerative disc herniation.[6]

It has been shown before that a narrow spinal canal, measured from radiographs, CT or MRI, is a significant risk factor for symptomatic degenerative disc herniation and spinal stenosis in adults.[7-12] In children and adolescents, smaller spinal canal dimensions have been identified in symptomatic disc herniation in studies using CT-myelogram.[13,14] No investigations have been published that use modern MRI, which provides superior soft-tissue resolution, in evaluating spinal canal dimensions and its effect on the success of non-operative treatment and need for operative treatment for disc herniation.

The purpose of this study was to investigate whether osseous spinal canal dimensions affect the need for discectomy in adolescent disc herniation patients.

Methods

This study was approved by the local ethical committee.

We retrospectively reviewed office charts of children and adolescents (aged 10 to 17 years) treated in our institution between June 2002 and October 2014 (Children's Hospital, Helsinki University Hospital) with ICD-10 diagnosis numbers M51.1, M54.1, M54.3, M54.4 and M54.5.[15] Patients who had received lumbar spine MRI were included in the study. All patients with congenital malformations, i.e. failures of segmentation, malignancies and diseases affecting bone structure, were excluded.

The study population consisted of 56 girls and 27 boys. Patients with surgically treated disc herniation formed group 1 (n = 19, age range 13.1 to 16.8 years). Indication for discectomy was presence of herniated disc, which comes into contact with nerve root on MRI study and exhibits radicular pain sensation on respective dermatome that is not responsive to conservative treatment. Patients with conservatively treated disc herniation formed group 2 (n = 17, age range 13.3 to 16.2 years). The conservatively

Table 1. Study groups.

	Girls		Boys		All data	
	n (%)	Age (SD)	n (%)	Age (SD)	n	Age (SD)
Group 1	11 (*57.9*)	15.52 (0.88)	8 (*42.1*)	15.67 (0.50)	19	15.58 (0.74)
Group 2	12 (*70.6*)	14.78 (1.01)	5 (*29.4*)	15.08 (0.53)	17	14.87 (0.90)
Group 3	33 (*70.2*)	14.55 (1.46)	14 (*29.8*)	14.05 (1.68)	47	14.40 (1.54)
Total	56 (*67.5*)	14.78 (1.33)	27 (*32.5*)	14.74 (1.43)	83	14.77 (1.37)

SD, standard deviation

treated group was defined as having disc herniation on MRI and presented with back pain with or without sciatica. Group 3 consisted of patients with LBP but no disc herniation on MRI (n = 47, age range 11.2 to 16.9 years) (Table 1).

Patients in groups 1 and 2 were initially treated conservatively, consisting of pain medication, activity restriction (sports etc. were allowed as tolerated) and observation. All operations were conducted in a standard manner. A midline approach was used and paravertebral muscles were detached subperiosteally down to the laminae. Partial laminotomy was conducted when necessary. Herniated disc material was removed to decompress the affected neural root. The surgeries were conducted with a microscope. Operations were conducted by four different senior surgeons in one hospital.

The MRI examinations were carried out with 1.5 Tesla scanners from Philips (Amsterdam, Netherlands), Siemens (Erlangen, Germany) or General Electric (Fairfield, Connecticut) and three examinations had been obtained with 3 Tesla Siemens scanners. The sequences followed the routine for the lumbar spine examinations. Due to the retrospective nature of this study, we had MR images taken with several different devices and MRI protocols, and some patients even lacked some imaging sequences. For example, if axial T2-weighted images were absent, we used T1-weighted images, which have identical reliability when analysing the dimensions of the osseous spinal canal. The sagittal diameter and width of the herniated disc were measured from sagittal and axial T2-weighted images when available and T1-weighted images, respectively. Space available for nerve root was measured from axial images.

We used an AGFA picture archiving and communication system (PACS) (Agfa, Mortsel, Belgium) and its tools for the measurements. The dimensions were measured with a PACS measuring device by manually defining points from MRI sections by two of the authors (OL and RK). The MRI measurements were obtained from the axial images perpendicular to the disc. We measured the dural sac (Fig. 1a) and the spinal canal areas at the disc level (Fig. 1b) and at pedicle level (Fig. 1c). In addition, we measured the midline anteroposterior (AP) diameter at the pedicle level (Fig. 1d). Measurements from the L3 vertebra downwards to the S1 vertebra are included in the study.

From lateral view radiographs, we measured the pedicle length between the posterior line of the corpus and the facet joint. From the posteroanterior view, we measured the interpedicular distance between the inner borders of pedicles. MRI scans and radiographs were blinded to the observers.

With transitional lumbar vertebrae, the unilaterally sacralised vertebra was named L5 and the bilaterally sacralised S1. The disc between the lowest lumbar vertebra and S1 was named presacral. Four patients had only four lumbar vertebrae. If a patient (n = 6) had six lumbar vertebrae, we decided to name the lowest vertebra L5.

Statistical analysis

All the measurements were independently obtained by authors (OL and RK). The final result was the average of these two measurements. With major disagreement (about 20% of the result), we remeasured that value to minimise the measuring error. Statistical analyses were conducted with Mann-Whitney U test and significance was set at $p < 0.05$. For the intraobserver error, we randomly chose ten patients and repeated the measurements. The interobserver error was defined by estimating the difference of the measurements between both observers. The observer reliability was conducted with intraclass correlation. Data analysis was conducted using the SPSS Statistics V22.0 (IBM, New York, New York).

Results

In patients with disc herniation, the number of girls dominated boys (23 *versus* 13, $p < 0.05$) but they showed no age differences (15.13 years *versus* 15.44 years, $p = 0.27$). A total of 25 patients had disc herniation at one level, ten patients at two levels and one patient at three levels. Our data totalled 48 herniated discs, of which 20 were operated (one patient had two operated discs).

Each of the 83 patients suffered from LBP. Limb pain was present in 19 patients in group 1, seven patients in group 2 and four patients in group 3. Time between the onset of the symptoms and the MRI was 6.4 months (0.5 to 24) in group 1 and 6.9 months (2 to 24) in group 2. The

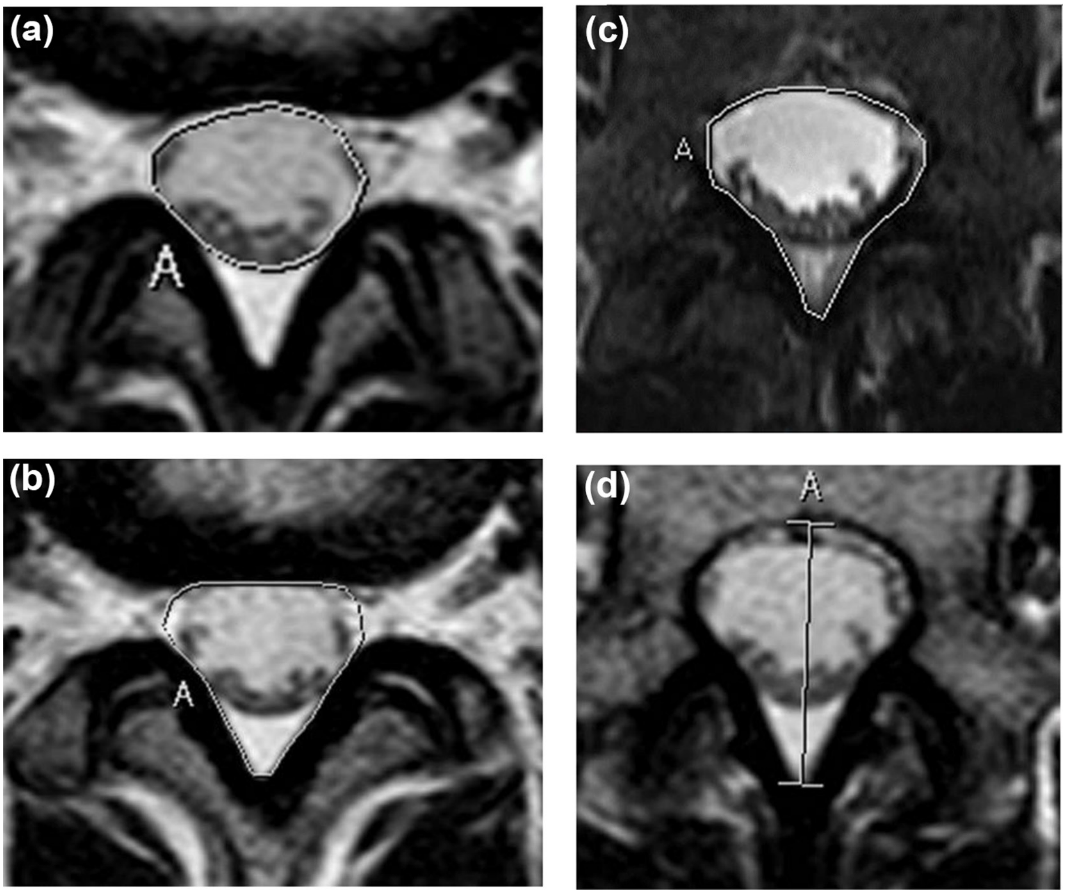


Fig. 1 Illustration of method of measuring: (**a**) dural sac area; (**b**) spinal canal area at disc level; (**c**) spinal canal area at pedicle level and; (**d**) spinal canal diameter at pedicle level.

surgical treatment was conducted in 8.0 months (1 to 30) after the onset of the symptoms.

In group 1, 17 (85%) discs were classified as protrusion and three (15%) as extrusion; similarly in group 2, 14 (82%) were classified as protrusion and three (18%) as extrusion as described before.[16]

There was no significant difference (p = 0.15) in the largest AP diameter of the displaced discs in the spinal canal between group 1 (6.05 mm SD 2.6) and group 2 (6.79 mm SD 1.9). However, between group 1 and group 2 there was a significant difference (p = 0.042) in the width of the herniated disc: in group 1, 15.65 mm SD 3.5 and in group 2, 13.29 mm SD 3.28. Measurements of space available for roots of axial cuts on the right side and left side were significantly smaller (p = 0.03 and 0.04, respectively) in group 1 (2.47 mm SD 2.02 and 2.01 mm SD 1.81, respectively) compared with group 2 (3.79 mm SD 1.97 and 3.18 mm SD 2.03, respectively).

In the MRI analysis, the spinal canal AP diameter and area were significantly smaller at the pedicle level on all spinal levels when comparing groups 1 and 3 (Fig. 2a and Table 2). Similarly, group 1 had significantly smaller spinal canal and dural sac areas at disc level than group 3 on all vertebral levels analysed (Fig. 2b and Table 2).

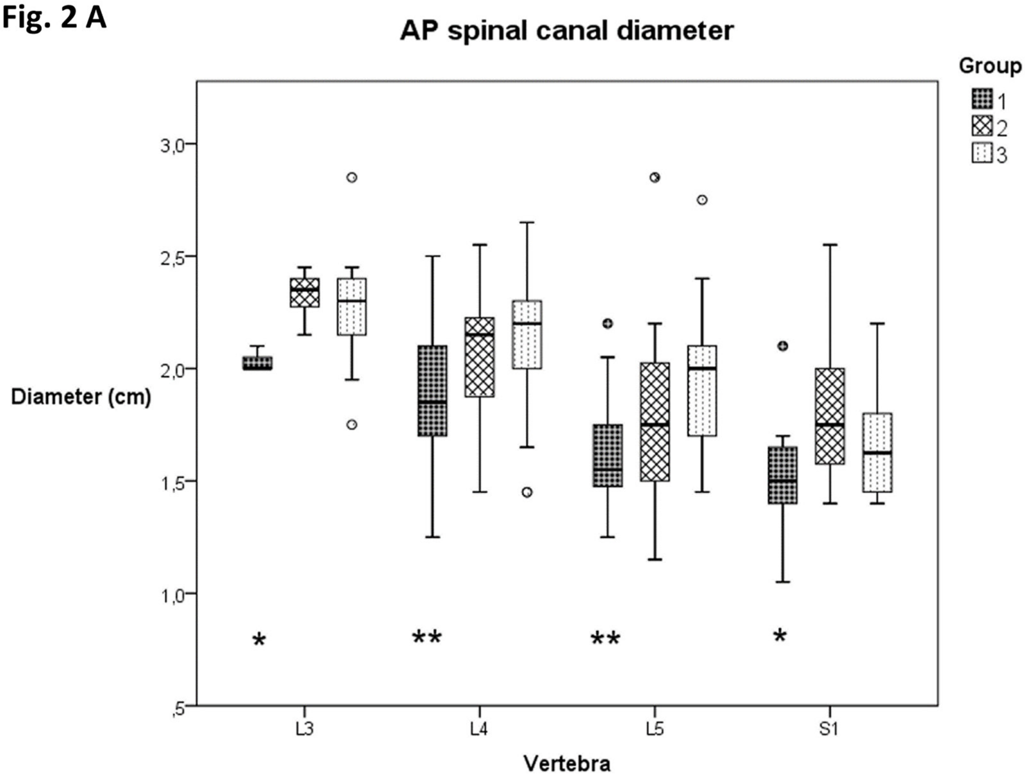
Compared with group 2, group 1 showed significantly smaller dural sac and spinal canal areas at disc level at L3 to L4 and presacral levels. Additionally, group 1 presented a significantly narrower AP spinal canal diameter and area than group 2 in the L3 and S1 vertebrae at pedicle level (Fig. 2 and Table 2).

Between genders, the MRI measurements showed no differences. In area measurements, intraobserver and interobserver agreement was > 0.9. The reliability was slightly lower in the AP spinal canal diameter (> 0.8).

Discussion

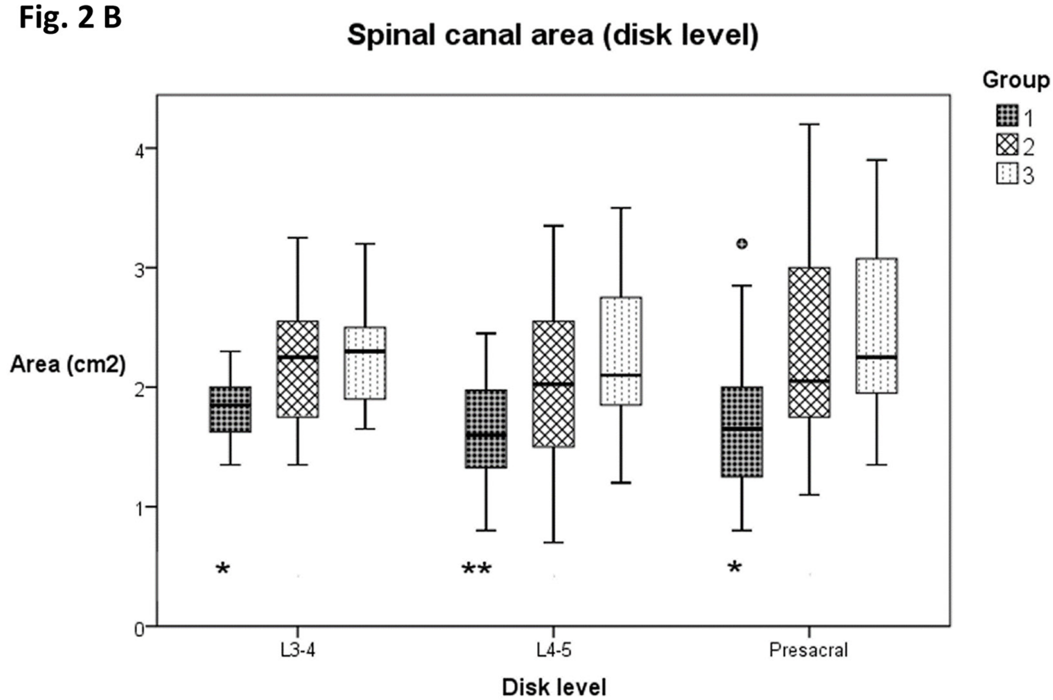
The goal of treatment of adolescent disc herniation is to relieve pain and allow early mobilisation. An initial trial of conservative treatment is an accepted standard. Compared with adult disc herniation, conservative treatment in adolescents does not lead to resolution of pain as reliably as in adults. In our study, time to first MRI was

Fig. 2 A



*Group 1 has a smaller AP spinal canal diameter than groups 2 and 3, **Group 1 has a smaller AP spinal canal diameter than group 3, (p<0.05). Small circles indicate the outliers of the data.

Fig. 2 B



*Group 1 has a smaller spinal canal area than groups 2 and 3, **Group 1 has a smaller spinal canal area than group 3, (p<0.05). A small circle indicates the outlier of the data

Fig. 2 (**a**) Spinal canal diameter at pedicle level and (**b**) spinal canal area at disc level (AP, anteroposterior).

Table 2. MRI measurements of spinal canal dimension.

Measurements				
Variable	Level	Group 1 (SD)	Group 2 (SD)	Group 3 (SD)
Dural sac area (cm²)	L3-4	1.24 (0.34)	1.43 (0.48)	1.56 (0.38)
	L4-5	0.89 (0.41)	1.15 (0.46)	1.52 (0.43)
	Presacral	0.68 (0.28)	1.09 (0.53)	1.26 (0.55)
Spinal canal area (cm²), disc level	L3-4	1.81 (0.28)	2.22 (0.54)	2.27 (0.45)
	L4-5	1.62 (0.47)	2.03 (0.72)	2.24 (0.54)
	Presacral	1.70 (0.62)	2.40 (0.97)	2.52 (0.85)
Spinal canal area (cm²), pedicle level	L3	2.25 (0.24)	2.59 (0.30)	2.50 (0.40)
	L4	2.16 (0.28)	2.41 (0.40)	2.51 (0.48)
	L5	2.14 (0.36)	2.73 (0.59)	2.77 (0.68)
	S1	2.41 (0.61)	3.26 (1.23)	3.26 (0.81)
AP diameter (cm)	L3	1.99 (0.11)	2.33 (0.11)	2.27 (0.22)
	L4	1.91 (0.29)	2.06 (0.31)	2.15 (0.28)
	L5	1.63 (0.26)	1.78 (0.43)	1.96 (0.28)
	S1	1.50 (0.23)	1.80 (0.29)	1.65 (0.23)
p-values				
Variable	Level	Group 1 and 2	Group 1 and 3	Group 2 and 3
Dural sac area	L3-4	0.193	0.020*	0.411
	L4-5	0.099	< 0.001*	0.018*
	Presacral	0.012*	< 0.001*	0.277
Spinal canal area, disc level	L3-4	0.041*	0.004*	0.777
	L4-5	0.098	< 0.001*	0.289
	Presacral	0.030*	< 0.001*	0.479
Spinal canal area, pedicle level	L3	0.050*	0.122	0.618
	L4	0.051	0.005*	0.543
	L5	0.002*	0.001*	0.943
	S1	0.070	< 0.001*	0.468
AP diameter	L3	0.003*	0.004*	0.341
	L4	0.095	0.002*	0.228
	L5	0.256	< 0.001*	0.080
	S1	0.002*	0.037*	0.072

*statistical significance

SD, standard deviation; AP, anteroposterior

6.4 months in patients requiring operative treatment for their symptoms. This may be due to variable symptoms of adolescent disc herniation as well as lack of awareness of lumbar disc herniation in adolescents. This may have consequences with prolonged pain that may adversely impact outcome of surgical intervention.[17,18]

In this study, disc herniation population presented more girls (64%). As previous studies have shown, the role of gender is controversial in adolescent disc herniation.[3,4,6,19] Girls aged < 16 years are suggested to be more vulnerable for lumbar disc herniation, whereas boys have a higher risk at 16 to 20 years of age.[19] The earlier growth spurt in girls has been suggested as one explanation for this phenomenon. In this study, no age differences appeared between sexes. It remains questionable if our study includes only boys with an early growth spurt. Boys with a later growth spurt may suffer from lumbar disc herniation at the age of 17 years and older when not treated in a children's hospital, which may explain the lack of age differences in this study.

Our groups presented slightly different age and gender profiles, the discectomy group being the oldest and having the largest proportion of boys. However, the age differences are insignificant for our measurements, because the cross-sectional lumbar spinal canal area matures by six years of age.[20] Gender had no effect on our measurements, as boys and girls presented no differences in the comparative analysis. Due to the retrospective nature of this study, we had MR images taken with several different devices and MRI protocols, and some patients even lacked some imaging sequences. For example, if axial T2-weighted images were absent, we used T1-weighted images, which have identical reliability when analysing dimensions of osseous spinal canal.[21]

Dora et al[11] presented with MRI a smaller spinal canal in adult discectomy patients compared with asymptomatic controls. In a CT study of adult patients, Kornberg and Rechtine[8] had similar study groups to our study and discectomy patients demonstrated smaller spinal canal dimensions than other patients.[8] Their results slightly differed from ours, as conservatively treated patients had a smaller spinal canal area and AP diameter than patients with LBP but no disc herniation. They also discovered that patients with poor surgical result had significantly smaller spinal canal dimensions than patients with good surgical results.

The normal spinal canal sagittal diameter in 15-year-old males at the L5 level is 20.1 mm SD 2.9.[22] In our data, patients without disc herniation (group 3) had sagittal diameter of 19.6 mm SD 2.8 at the L5 level. These results are in concordance. One way to define 'small canal size' could be under 2 SD of normal. This would be less than 14.3 mm at the L5 level. In patients requiring operative treatment for disc herniation (group 1), the sagittal diameter at the L5 level was 16.3 mm SD 2.6. Although the spinal canals are significantly smaller in group 1, there is significant overlapping between groups and numerical limits for clinical use cannot be provided by this study

Both our methods to determine the osseous spinal canal size from MRI, the spinal canal area at disc and pedicle level as well as AP diameter, were relatively uniform, as significant results came out at same levels. Both of these measurements have positive and negative qualities. Occasionally, the spinal canal has a relatively long and narrow posterior part, which can form even a third of the AP spinal canal diameter impacting little on the actual spinal canal size. The spinal canal area, measured at the disc level, provides a more realistic estimate on the space available for neural structures in case of disc herniation. On the other hand, a large herniation complicates estimating the borders of the osseous spinal canal. Nevertheless, the discectomy patients also had a smaller spinal canal area at the L3 to L4 level, where the number of herniations, and therefore the distracting factor with measurements, was minor. The measurements of the spinal canal area were more reliable and repeatable than the AP spinal canal diameter. It is possible that the errors of the AP diameter resulted from the challenge of choosing the right slice from MRI, especially when the pedicle level cannot be defined unequivocally. We observed that the AP spinal canal diameter may considerably vary between two adjacent slices, leading to possible errors.

Measurements of the size of the herniated disc in the spinal canal showed that the AP diameter did vary between groups 1 and 2. Although the width of the herniation was larger in group 2, the space available for roots was significantly smaller in group 1 due to smaller osseous dimensions. This suggests that the symptoms generated by herniation are directly related to the osseous size of the spinal canal.

Previous studies have shown a connection between short pedicle in radiographs and symptomatic disc herniation in adults.[23] In our data, we fail to demonstrate correlation of radiographs to symptomatic disc herniation. Radiographic measurements showed no differences between group 1 and the other groups. Group 3 presented shorter L2 and L3 pedicles than group 2. Girls presented a narrower interpedicular distance in L1, L3, L4 and L5 vertebrae. We discovered that estimating the pedicle length in radiographs is not comparable with MRI pictures, which allows normalisation of vertebral rotation. Many patients presented either scoliosis or rotation of lumbar spine, as a reaction to pain, which led to an oblique projection of lumbar vertebrae, this may lead to a false interpretation of the spinal canal AP diameter. This phenomenon is emphasised in children, whose spine is more flexible than the stiff and degenerated spine of adults. In addition, the pedicle length in radiographs proved to be the most unreliable of our measurements in intraobserver and interobserver analyses and it correlated poorly with the spinal canal MRI measurement.

Trauma plays a prominent role in adolescent herniation and, unlike in adults, the disc tissue found juvenile herniation is firm and fibrous and is more of a small protrusion than the larger herniations typically found in adults.[24] Thus, space available for neural tissues is of paramount importance, especially in adolescent herniation. Previously, it has been suggested in studies conducted with CT-myelogram on small patient groups that congenital stenosis is more frequent in symptomatic adolescent disc herniation.[13,14] This study has been conducted using MRI scans, which provide superior soft-tissue resolution compared with CT-myelogram. In addition, we have compared patients with disc herniation managed conservatively and operatively. Our results suggest that small spinal canal dimensions negatively affect outcome of conservative treatment of adolescent disc herniation.

Limitations to this study are retrospective design and small size of patient groups. The results were likely limited by small sample size, especially between disc herniation groups. On the other hand, the number of patients exceeds most other adolescent studies examining disc herniation.

In conclusion, our results suggest that a small spinal canal size increases the need for discectomy in adolescent disc herniation. This finding is evident when comparing discectomy patients to both patients with conservatively treated herniation and patients with no herniation. This indicates that space for neural structures is critical in the outcome of adolescent disc herniation and a small spinal canal may worsen the prognosis of conservative treatment and increase the need for operative treatment of adolescent disc herniation.

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COMPLIANCE WITH ETHICAL STANDARDS

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No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical Approval: All studies involving human participants were in accordance with an institutional research committee and with the 1964 Helsinki declaration. This article does not contain any studies with animals.

Informed Consent: A waiver of informed consent was granted form our institutional review board for all participants involved in this study.

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