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Comparison of conus medullaris levels and spinopelvic parameters between patients with adolescent idiopathic scoliosis, tethered cord syndrome, and healthy adolescents

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Abstract

Aim: The tension of the spinal cord may pose a risk in terms of neurological damage during deformity correction of spine surgeries. Conus medullaris level can provide information about the tension of the spinal cord. However there is lack of information in the literature about the conus medullaris level in idiopathic scoliosis patients. This study aimed to compare conus medullaris levels and spinopelvic parameters among patients with adolescent idiopathic scoliosis (AIS), tethered cord syndrome with AIS, and healthy controls.

Materials and Methods: We retrospectively recruited fifty patients with AIS (mean age 14.3±2.0 years), forty-two patients with tethered cord syndrome with AIS (mean age 13.6±4.8 years), and fifty patients with no spinal abnormality (mean age 14.5±2.4 years). For the evaluation of and comparison of the patients, Risser stage, spinopelvic parameters (Cobb angle, lumbar lordosis angle, thoracal kyphosis angle, lumbosacral angle, thoracal tilt, T1-pelvis angle, sacral slope, sagittal and coronal balance, lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence), and conus medullaris levels were used. Conus medullaris levels were measured on sagittal magnetic resonance imaging (MRI) T2-weighted sections, and spinopelvic parameters were measured on lateral whole-spine radiographs.

Results: Conus medullaris termination levels were significantly lower in the tethered cord syndrome with AIS group ($p < 0.001$) and were not significantly different between the AIS group and healthy individuals ($p = 0.680$). No significant differences were observed in the Risser stage, Cobb angle, lumbar lordosis, thoracal kyphosis, lumbosacral angle, thoracal tilt, T1-pelvis angle, sacral slope, sagittal balance, and coronal balance between the tethered cord with AIS and AIS groups (all $p > 0.05$). Lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence parameters were significantly higher in the tethered cord with AIS group (all $p < 0.05$).

Conclusion: This study demonstrated that the distribution of the conus locations in AIS patients was similar to that in the healthy control group. Lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence parameters were significantly higher in the tethered cord syndrome with AIS group.

Introduction

The termination level of the conus medullaris is known to vary in typical populations [1–4]. It reaches the adult level, namely the T2 to L3 vertebra, before the age of two years [5–7]. The conus medullaris level may also vary according to age, sex, and body posture [2, 8]. In cases where the conus medullaris is located beneath the L3 vertebral level, the spinal cord is considered low lying if it cannot be proven that the spinal cord is not stretched by a mass such as a bony suprastructure, fibrous band, or terminal lipoma [9]. By contrast, patients with clinical signs and symptoms, such as motor weakness, urinary incontinence, may have a stretched cord even when the conus medullaris level is normal [10]. In the literature, few studies have evaluated conus medullaris levels in patients with spinal deformities and tethered cord syndrome [11–13].

Primary tethered cord syndrome is characterized as be-

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low the location of the abnormally thickened filum terminale. Secondary tethered spinal cord syndrome arises from meningomyelocele, intradural tumors, trauma, surgeries, or acquired deformities [14]. Scoliosis is present in 25% of tethered spinal cord syndrome cases [15]. Such scoliosis is associated with neural axis abnormalities such as Chiari malformation, stretched spinal cord, lipomas, diastematomyelia, and intraspinal cysts [16].

Sagittal plane alignment of the spine and the interrelation with the pelvis are both important in scoliosis surgery. Spinopelvic parameters are widely used to evaluate sagittal balance, and each spinopelvic parameter has a significant effect on overall balance. Both preoperative planning and postoperative complications are affected by changes in sagittal spinopelvic parameters [17–21]. Thus, comparative changes in conus medullaris levels and sagittal spinopelvic parameters must be investigated to decrease postoperative complications and ensure correct preoperative planning. This study aimed to compare conus medullaris levels and sagittal spinopelvic parameters between patients with tethered cord syndrome with adolescent idiopathic scoliosis (AIS), only AIS, and healthy controls.

Materials and Methods

A total of 142 patients were included in this study, and there were three groups of patients. Group-1 had fifty patients (16 males and 34 females, mean age 14.3 ± 2.0) who had undergone surgery for AIS. Group-2 had forty-two patients (12 males and 30 females, mean age 13.6 ± 4.8) who had undergone surgery for tethered cord syndrome with AIS. Group-3 (control group) had fifty healthy patients with similar age and sex distribution (23 males and 27 females, mean age 14.5 ± 2.4) without any structural abnormalities, and these patients were randomly selected for the comparison group. All patients in group-1 and group-2 had undergone posterior instrumentation with pedicle screws and fusion at our hospital between 2012 and 2016. Tethered cord syndrome patients also underwent untethering surgery before corrective surgery with posterior instrumentation and fusion. The inclusion criteria of the study were to be operated for AIS (group-1) or tethered cord with AIS (group-2) or to be healthy individuals (group-3: control group). Patients were excluded from the study if their medical records and radiologic images were insufficient or if they had undergone revision surgery.

Radiologic investigations included whole-spine magnetic resonance imaging (MRI) and lateral radiographs. The vertebral body and intervertebral disk were defined as a spinal unit. The spinal unit had four parts: the vertebral body divided into the upper, middle, and lower segments of the vertebral body and the intervertebral disk. The conus medullaris termination level was defined as the most distal point of the cord. Three midline sagittal T2-weighted images were used to precisely determine the junction between the cord and the cauda equina [8]. A straight line was drawn perpendicular to the long axis of the spinal cord at the vertebral bodies and disc space [22] (Figure 1).

For the sagittal plane analysis, thoracic kyphosis, lumbar lordosis, sagittal balance, sacral slope, pelvic tilt, pelvic incidence, lumbosacral angle, lumbar tilt, thoracic tilt, T1-pelvis angle, and pelvic obliquity were measured by an orthopedic surgeon blinded to the purpose of this study.

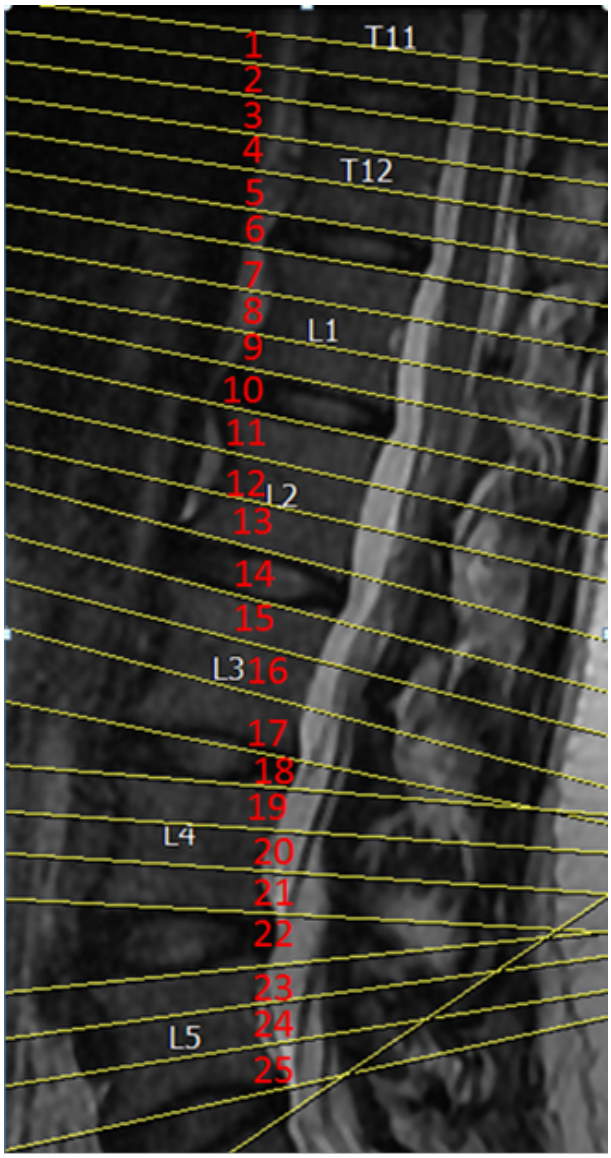

Figure 1. The measurement method of conus medullaris on MRI.

Statistical analyses were performed using SPSS IBM Statistics 22 (IBM, Armonk, New York, USA). The mean, standard deviation, median, lowest, highest, frequency, and ratio values were calculated as descriptive statistics of the data. The distribution of variables was measured using the Kolmogorov Smirnov test. The independent Kruskal-Wallis and Mann-Whitney U tests were used for the analysis of independent quantitative data. To determine the statistically different groups after the Kruskal-Wallis test, we used the Mann-Whitney U test with Bonferroni correction. The Chi-Square test was used for the analysis of independent qualitative data. A p-value < 0.05 was considered statistically significant. The sample size was determined by comparing spinal cord ending levels of patients with tethered cord syndrome + AIS patients with AIS patients or healthy control group, which is one of our main results. The statistical power of the study was %100

according to the post-hoc power analysis (alpha [type I/II error rate]: 0.05) for retrospective studies.

Results

The age and sex distributions of the three groups are shown in Table 1 and Table 2. The conus medullaris termination level in the tethered cord group was significantly lower than that in the adolescent idiopathic scoliosis group and normal healthy group ($p<0.001$ and $p<0.001$, respectively). There was no significant difference in the conus medullaris termination level between the adolescent scoliosis group and the healthy control group ($p = 0.754$).

The filum terminale level in the tethered cord group was significantly lower than that in the adolescent idiopathic scoliosis group and normal group ($p<0.001$ and $p<0.001$, respectively). In the adolescent idiopathic scoliosis group, the filum terminale level was significantly higher than that in the normal group ($p<0.001$).

The Risser stage, Cobb angle, lumbar lordosis, thoracic kyphosis, lumbosacral angle, thoracic tilt, T1-pelvis angle, sacral slope, sagittal balance, and coronal balance measurements did not differ significantly between the tethered cord and adolescent idiopathic scoliosis groups (Table 3). However, there were significant differences concerning lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence between the tethered cord and adolescent idiopathic scoliosis groups (Table 3).

Discussion

The most important finding was that lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence parameters were significantly higher in the adolescent idiopathic scoliosis with tethered cord group compared with the adolescent idiopathic scoliosis group and healthy control group.

The termination level of the conus medullaris has been evaluated in several previous studies [1–4]. The termination level of the conus medullaris may be normal or higher in scoliosis patients [12]. Raghavan et al. [11] reported that in tethered spinal cord patients, the conus medullaris ended at the L3 spine level in 30% of the cases, the L4 or L5 spine level in 30% of cases, and at the S1-2 spine level in 8–10% of cases. In our study population, 57% of patients with tethered cord ended at the L4 level, 33% at the L3 level, and 10% at the L2 level.

In a magnetic resonance imaging (MRI) study by Sun et al. [12], no significant differences in the conus medullaris levels of the spinal cord were found between healthy individuals and adolescent idiopathic scoliosis patients. Similarly, in our study, no statistically significant difference was found between the healthy group and the adolescent idiopathic scoliosis group.

In scoliosis patients with a tethered spinal cord, the traditional treatment method is spinal cord release followed by correction [9]. All of the patients included in our study underwent this two-stage surgery.

Increases in pelvic incidence, pelvic tilt, or knee and hip flexion contracture are predisposing factors for coxarthrosis [23]. In our study, increased pelvic incidence and increased pelvic tilt were found in tethered cord patients. Thus, tethered cord patients are at risk of future development of coxarthrosis.

Takeshita et al. demonstrated that pelvic obliquity is an important parameter affecting sitting balance and that nonambulatory neuromuscular scoliosis patients show increased pelvic obliquity [24]. This may lead to the formation of persistent pressure wounds due to an inappropriate sitting position of the patients. In our study, the significant increase in pelvic obliquity caused impaired sitting balance in tethered spinal cord patients. Pelvic obliquity should thus be included in the calculations when planning correction in tethered spinal cord patients.

The most important risk factors for the progression of the curve in tethered spinal cord patients are the patients' age and the size of the curvature [25]. Corrective surgery is usually not needed after untethering the conus medullaris in patients with a Cobb angle of 30° or less [25]. Chernet al. showed that medullary release in patients with scoliosis of 35° or less would stop the progression of the curve and reduce the need for its correction [26]. Flynn et al. showed that a double major curve is a risk factor for the progression of curvature in tethered cord patients [27]. In our study, the mean Cobb angle was 46.6° ± 22.8° in tethered cord patients, and 15 of 42 patients (36%) had a double major curve.

According to Schwab's classification of adult vertebral deformities, there is a strong association between pelvic incidence (PI) and lumbar lordosis (LL) [28]. A difference of 10° between PI and LL is considered normal [29]. Bhalla et al. [30] consider pelvic tilt below 20° normal. Greater osteotomies are required to achieve sagittal and coronal balance in scoliosis patients with increased pelvic tilt. Ideal spinal alignment achieves balance by consuming the intended minimum muscle energy. Simultaneously, when PI-LL is larger than 10°, the risk of developing back pain increases [30]. There was a significant increase in pelvic tilt in tethered spinal cord patients relative to adolescent idiopathic scoliosis patients in our study population, which means that larger corrective osteotomy may be needed in these patients. They may be at greater risk of complications.

When lumbar lordosis is decreased, the pelvis turns toward the posterior from the pelvis center, and sacral translation increases to compensate. In this way, the C7 plumb line is centered. If lumbar lordosis is decreased and the pelvis cannot rotate posteriorly to correct the sagittal balance, hip flexion contracture can develop. Increased hamstring tension can also cause flexion contracture [10]. Decreased lumbar lordosis may explain the hip and knee flexion contractures observed in tethered spinal cord patients. In our study, a mild decrease in lumbar lordosis was found in tethered cord patients relative to adolescent idiopathic scoliosis patients, although the difference was not statistically significant.

In a study by Lafage et al., the quality of life was adversely affected in scoliosis patients in the presence of positive sagittal balance and pelvic retroversion [31]. In long-term follow-up studies, pain and disability were associated with pelvic retroversion. One of the treatment goals in children with scoliosis is to bring sagittal alignment, especially pelvic tilt, to the normal values.

Table 1. The age and sex distributions of three groups.

		Tethered Cord with AIS	AIS	HealthyControl	p
Age	Mean ± SD	13.6 ± 4.8	14.3 ± 2.0	14.5 ± 2.4	0.75
	Median (Min-Max)	15 (2 – 27)	15 (10 -18)	15 (10 -18)	
Gender	Male (n, %)	12, 29%	16, 32%	23, 46%	0.17
	Female (n, %)	30, 71%	34, 68%	57, 54%	

AIS: Adolescent idiopathic scoliosis

Table 2. The termination levels of Conus Medullaris and Filum Terminale

		Tethered Cord with AIS	AIS	HealthyControl	p
Conus Medullaris Level	Mean ± SD	19.0 ± 2.9	8.6 ± 2.7	8.0 ± 3.0	<0.001
	Median (Min-Max)	20 (12 – 22)	9 (2 -20)	8 (4 -19)	
Filum Terminale Level	Mean ± SD	9.4 ± 2.0	7.0 ± 1.5	7.6 ± 1.8	<0.001
	Median (Min-Max)	9 (6 – 14)	7 (3 -9)	8 (2 -11)	

AIS: Adolescent idiopathic scoliosis

Table 3. Comparison of sagittal and coronal spinopelvic parameters between tethered cord syndrome with adolescent idiopathic scoliosis (AIS) and AIS patients.

	Tethered Cord with AIS		AIS		
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)	p
Risser grade	3.5 ± 1.6	4 (0 – 5)	3.9 ± 0.8	4 (2 – 5)	0.570
Cobb angle	46.6 ± 22.8	47 (12 - 97)	47.8 ± 15.2	47(11 - 82)	0.683
Lumber lordosis angle	41.1 ± 21.5	39 (1 - 98)	44.8 ± 11.7	44 (20 - 74)	0.167
Thoracic kyphosis angle	24.1 ± 16.3	20 (4 - 64)	30.1 ± 15.2	27 (6 - 70)	0.051
Lumbosacral angle	12.6 ± 10	10 (1 - 46)	8.5 ± 5.5	8 (1 - 27)	0.084
Toracic tilt angle	0.4 ± 16.3	2 (43 - 41)	6.1 ± 12.4	6 (28 - 40)	0.079
Lomber tilt angle	42 ± 22.6	40 (2 - 100)	47.4 ± 14.8	45 (9 - 104)	0.049
T1 Pelvic angle	43.7 ± 20.6	47 (2 - 78)	49.1 ± 8.2	50 (28 - 73)	0.505
Pelvic obliquity angle	4.2 ± 4.0	3 (0 - 19)	3.4 ± 11.6	2 (0 - 83)	<0.001
Pelvic Tilt angle	19.8 ± 13.4	17 (3 - 64)	13.3 ± 8.3	11 (3 - 37)	0.019
Sacral Slope angle	37.9 ± 17.5	34 (9 - 93)	33.2 ± 8	32 (19 - 55)	0.317
Pelvic incidence angle	57.6 ± 21.8	55 (26 - 128)	46.5 ± 11.8	46 (25 - 74)	0.016
Sagittal balance (mm)	-0.2 ± 36.1	-8 (-73 - 98)	-15.3 ± 35.8	-20 (-87 - 81)	0.069
Coronal balance (mm)	1 ± 23.7	-1 (-60 - 57)	4.1 ± 17	7 (-40 - 35)	0.388

This study has several limitations. First, the relatively small sample size may influence the statistical results. Second, the lack of rotational measurements may affect sagittal plane measurements. To the best of our knowledge, this is the first study comparing conus medullaris termination levels and sagittal spinopelvic parameters between tethered cord syndrome + AIS patients, AIS patients, and healthy individuals.

Conclusion

This study demonstrated that the distribution of the conus locations in AIS patients was similar to that in the healthy group. Lumbar tilt, pelvic obliquity, pelvic tilt, and pelvic incidence parameters were significantly higher in the adolescent idiopathic scoliosis with tethered cord group. The likelihood of hip and knee flexion contractures was increased relative to that in adolescent idiopathic scoliosis patients, which explains the deterioration in sitting and walking balance in patients with tethered spinal cord syndrome.

Ethical Approval

This study was approved by our institutional review board with date 27/05/2015 and number 24. This article does not contain any studies with human participants or animals performed by any of the authors.

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