Indication for preoperative MRI of neural axis abnormalities in patients with presumed thoracolumbar/lumbar idiopathic scoliosis

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Abstract

Purpose The purpose of this study was to investigate the incidence of neural axis abnormalities in patients with presumed “idiopathic” thoracolumbar or lumbar scoliosis by magnetic resonance imaging (MRI) and try to determine which clinical and radiographic characteristics correlate with neural axis abnormalities on MRI in these patients.

Methods The database of a single spinal deformity center was retrospectively reviewed to identify all patients with a primary diagnosis of idiopathic scoliosis (IS) between January 2003 and August 2011. A total of 446 patients with main thoracolumbar or lumbar curves were identified. Radiographic parameters including main curve Cobb angles, location of curve apex, span of main curve, thoracic kyphosis (T5–T12), thoracolumbar junction kyphosis (T10–L2), lumbar lordosis (L1–S1), and sagittal and coronal balance were measured.

Results Neural axis abnormalities were detected in 35 (7.8 %) patients. For patients with neural axis abnormalities, a higher proportion of male gender and long thoracolumbar curves were presented. In these patients, the mean age was smaller and the mean Cobb angle of main curve was larger. Greater thoracic kyphosis ($\geq 30^\circ$) was more frequently found in those with neural axis abnormalities. The incidences of thoracolumbar junction hyperkyphosis were similar between two groups

($P > 0.05$). There was no difference between two groups as to lumbar lordosis and coronal and sagittal balance.

Conclusion We recommend the routine use of MRI in the patients with one or more of the following characteristics: right curves, long curve span, apex at thoracolumbar spine and hyperthoracic kyphosis.

Keywords Thoracolumbar/lumbar idiopathic scoliosis · Neural axis abnormalities · MRI

Introduction

Idiopathic scoliosis (IS) is the most commonly seen spinal deformity, whose etiology has been unknown. The diagnosis of IS is one of exclusion, and should be made after excluding other underlying etiologic factors including neuromuscular or skeletal congenital anomalies, or inflammatory or demyelinating processes [1, 2]. In some patients with neural axis abnormalities, scoliosis could be the only clinical sign, and would always be falsely classified as an “idiopathic” form [3, 4]. Previous studies have demonstrated that the existence of neural axis abnormalities would add the risks of neurologic injury during correction surgery for scoliosis [5, 6]. Therefore, it is necessary to investigate and, if required, to manage these abnormalities before surgery. Magnetic resonance imaging (MRI) seems to be a good modality that could clearly illustrate neural axis abnormalities with the advantages of better visualization of soft tissues and absence of radiation. However, the routine use of MRI is controversial, and the indications for MRI in presumed “idiopathic” scoliosis vary from study to study [7–10]. Many predictive factors, including curve pattern, age, gender, radiographic parameters and the presence of abnormal findings on the history

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or physical examination have been proposed when deciding whether or not to image the neural axis in patients with presumed “idiopathic” scoliosis [4–8]. Among these factors, curve pattern may be the most widely recognized and simplest sign to predict the presence of neural axis abnormalities. The presence of atypical curve patterns, such as left thoracic curve and double thoracic curve, was considered as a strong indication for performing MRI [11–13]. However, majority of these studies were focused on the patients with thoracic curves, and there is no study specifically investigating the incidence of neural axis abnormalities in patients with presumed “idiopathic” thoracolumbar or lumbar curves. The objective of this study is to determine which clinical and radiographic characteristics correlate with neural axis abnormalities on MRI in these patients.

Materials and methods

The database of a single spinal deformity center was retrospectively reviewed to identify all patients with a primary diagnosis of IS between January 2003 and August 2011. Patients were selected on the basis of the following inclusion criteria: (1) with a presumed main thoracolumbar or lumbar idiopathic scoliosis with apex from T12 to L4; (2) Cobb angle $>40^\circ$; (3) no associated syndrome; (4) absence of skeletal anomalies of spine; (5) no neurologic findings on physical examination and by history; (6) with whole spine MRI including craniocervical junction, cervical, thoracic, lumbosacral regions and terminal filament. A total of 446 patients who met the inclusion criteria were identified, including 79 males and 367 females. The mean age of the patients was 14.6 years (range 8–18 years).

Standing posteroanterior and lateral full-spine radiographs were obtained. Radiographic parameters including main curves Cobb angles, location of curve apex, span of main curve, thoracic kyphosis (T5–T12), thoracolumbar junction kyphosis (T10–L2), lumbar lordosis (L1–S1), and sagittal and coronal balance were measured. Thoracolumbar curve was defined when apex was at T12 or T12/L1 disc or L1, while lumbar curve was defined when apex was at L1/2 disc to L4 [14]. Curve apex was defined as the vertebra at the center of curve, and span of main curve was described from upper-end vertebra to lower-end vertebra. Coronal balance was measured by drawing a plumbline from the centre of the C7 vertebra and recording the amount of deviation from the midline of the sacrum, and sagittal balance was calculated by drawing a plumbline from the centre of C7 and recording the perpendicular distance from the posterior corner of the sacrum. Normal coronal or sagittal balance was defined as less than 20 mm from the plumbline [15].

Neural axis abnormalities were defined as the abnormalities affecting neural axis detected by the MRI, including Chiari, syrinx, tethered cord and so on [16]. The diagnosis of a Chiari 1 malformation was made when the herniation of the tonsils was below the foramen magnum by 5 mm or more [17].

Statistical analysis

Patients with neural axis malformations were compared to those without neural axis abnormalities for curve severity, span of thoracolumbar or lumbar curves, lumbar lordosis and age at first visit using independent sample *t* tests. Fisher’s exact test was used to compare gender distribution, curve pattern, level of apical vertebra, and distributions of thoracic kyphosis, thoracolumbar kyphosis, and coronal and sagittal balance between the two groups. Differences with a *P* value less than or equal to 0.05 were considered statistically significant.

Results

Neural axis abnormalities were detected in 35 (7.8 %) patients, including Chiari 1 malformation in 8 patients, Chiari 1 malformation with syringomyelia in 22, syringomyelia in 4, and tethered cord in 1. There were 22 males and 13 females in patients with neural axis abnormalities, whereas 57 males and 354 females in those without neural axis abnormalities. A higher proportion of males presented in patients with neural axis abnormalities ($P = 0.003$). The mean ages of patients with and without neural axis abnormalities were 13.5 ± 2.8 and 14.7 ± 1.7 years, respectively. The mean age of patients with neural axis abnormalities was smaller than those without ($P = 0.017$). Of patients with neural axis abnormalities, 19 had right thoracolumbar or lumbar curves and 16 had left thoracolumbar or lumbar curves, while in those without neural axis abnormalities, 36 had right thoracolumbar or lumbar curves and 375 had left thoracolumbar or lumbar curves. A higher proportion of right thoracolumbar or lumbar curves presented in patients with neural axis abnormalities ($P < 0.0001$). In patients with neural axis abnormalities, 32 had main thoracolumbar and 3 had main lumbar curves, and in those without neural axis abnormalities, 226 had main thoracolumbar and 185 had main lumbar curves. Neural axis abnormalities were more likely detected in patients with main thoracolumbar curves ($P < 0.0001$). The mean span of main curves was longer in patients with neural axis abnormalities when compared with that in patients without (7.5 vs. 6.1 , $P = 0.006$). The Cobb angle of main curve was larger in patients with neural axis abnormalities as compared to those without (57.7° vs. 47.0° ,

$P < 0.05$). Greater thoracic kyphosis ($\geq 30^\circ$) was more frequently found in those with neural axis abnormalities, when compared with those without (42.9 vs. 5.4 %, $P < 0.05$). The incidences of thoracolumbar junction hyperkyphosis were similar between two groups (42.1 vs. 51.4 %, $P > 0.05$). There was no difference between two groups as to lumbar lordosis and coronal and sagittal balance (Table 1; Figs. 1, 2).

Discussion

The incidences of neural axis abnormalities in presumed IS patients vary from study to study, ranging from 2.9 to 37 % [16, 18–21]. The heterogeneities of these studies were mainly from four aspects. First, the sample size was not adequate to draw conclusive results in some studies. Hausmann et al. [22] claimed the incidence of neural axis abnormalities in left thoracic scoliosis as high as 50 %, and proposed left thoracic scoliosis as a strong predictor for neural axis abnormalities. However, only 1 of 2 patients with left thoracic scoliosis was found to have neural axis abnormalities in his study, and the conclusion was not persuasive. Wu et al. [13] then specifically investigated

MRIs of 68 patients with left thoracic scoliosis, and confirmed the high incidence (54 %) of neural axis abnormalities in left thoracic scoliosis. Diab's study included the largest volume of presumed AIS patients, reporting a 4.3 % incidence of neural axis abnormalities in 923 patients. However, the curve pattern of scoliosis in this series was miscellaneous, and the incidence was not stratified accordingly. Richards et al. [23] conducted a prospective multi-center study to specifically evaluate a 6.8 % incidence of neural axis abnormalities in 529 presumed AIS patients with Lenke 1–4 right thoracic scoliosis. The flaw of Richards's study might be that the indications for MRI may be various among different centers. In this study, 446 patients with main thoracolumbar or lumbar scoliosis were included, which could represent the largest volume of samples in a single center. We believe that the sample size of our study is adequate enough to draw powerful conclusion. Second, the source of patients was heterogeneous. Nakahara et al. [18] reviewed the MRIs of 472 consecutive outpatients reporting a 3.8 % incidence of neural axis abnormalities. Diab et al. [19] reported a 9.9 % incidence of neural axis abnormalities in 2,206 consecutive patients who received correction surgery with the use of MRI. Overall, the incidence of neural axis abnormalities was

Table 1 Clinical and radiographic characteristics of patients with and without neural axis abnormalities

	MRI		P value
	Normal	Abnormal	
Age (year)	14.7 $\pm$ 1.7 (10–18)	13.5 $\pm$ 2.8 (8–18)	0.017
Cobb angle ($^\circ$)	47.0 $\pm$ 8.2 (41–88)	57.7 $\pm$ 15.5 (40–95)	0.003
Gender			
Male	57	22	<0.0001
Female	354	13	
Curve direction			
Right	36	19	<0.0001
Left	375	16	
Curve type			
Thoracolumbar	226	32	<0.0001
Lumbar	185	3	
Span of curve (levels)	6.1 $\pm$ 0.8 (4–9)	7.5 $\pm$ 1.2 (5–10)	0.006
Thoracic kyphosis			<0.0001
$\geq 30^\circ$	22	15	<0.0001
$< 30^\circ$	389	20	
Thoracolumbar kyphosis			
$\geq 10^\circ$	173	18	0.292
$< 10^\circ$	238	17	
Lumbar lordosis ($^\circ$)	–48.3	–50.2	0.329
Coronal balance	246	19	0.592
Coronal imbalance	165	16	
Sagittal balance	148	14	0.715
Sagittal imbalance	263	21	

Fig. 1 A 16-year-old male patient had a right-sided thoracolumbar curve with a Cobb angle of 73° . Apical vertebra was at T12 and the span of lumbar curve was 7. MRI showed Chiari malformation and syringomyelia

Fig. 2 A 12-year-old female patient had a right-sided thoracolumbar curve with a Cobb angle of 68° . Apical vertebra was at T12 and the span of thoracolumbar curve was 8. MRI showed Chiari malformation

higher in surgically treated patients. Third, the ages of patients included were different. Dobbs [20] found a 21.7 % prevalence of neural axis abnormalities in 46 patients with infantile IS. In another study, Pahys et al. [21] also reported an incidence in infantile IS as high as 13 %. In a study consisting of juvenile IS and AIS patients, the neural axis abnormalities occurred in 14.3 % juvenile IS patients, while no AIS patient was detected to have these abnormalities [16]. It seems that neural axis abnormalities are more frequently detected in young IS patients. Fourth, the incidences of neural axis abnormalities may be different between patients with and without abnormal neurologic findings on physical examination. Inoue et al. evaluated 250 patients who were classified as having “idiopathic” scoliosis at first presentation and admitted for spinal surgery, finding that 26 (57 %) of 46 patients with abnormal neurologic signs and 18 (9 %) of 204 patients without abnormal neurologic signs had neural axis abnormalities on MRI [1]. Obviously, abnormal neurologic findings were highly related to neural axis abnormalities [16]. In our study, all the surgically treated patients had no abnormal neurologic findings, and the overall incidence of neural axis abnormalities was 7.8 % in patients with thoracolumbar or lumbar scoliosis. Similar to other studies, the majorities of the abnormalities in our series were Chiari 1 malformation or syringomyelia or combined. Previous studies have demonstrated that a large proportion of patients with Chiari 1 malformation or syringomyelia have no other clinical symptom except scoliosis [24, 25].

Sexual dimorphism was one of the significant features of IS, and considered to be related to the etiopathogenesis of AIS. In AIS patients who received surgeries, the ratio of female to male could reach 10:1, whereas in scoliotic patients with neural axis abnormalities, this dimorphism is not so significant [9, 10, 21]. Loder et al. [26] compared the difference of gender distribution between patients of Chiari 1 malformation and AIS patients, demonstrating that the group of Chiari 1 malformation had a higher proportion of males than AIS group (37 vs. 8 %, $P < 0.01$). Wu et al. [13] investigated the prevalence of neural axis abnormalities in asymptomatic patients with left thoracic scoliosis finding that the ratio of male to female was over 2:1 (25 vs. 12) in 37 patients who had neural axis abnormalities. In our study, the ratio of male to female was 1:10 in IS patients while close to 2:1 in patients with neural axis abnormalities. It seems that the male gender could also be a strong indication for neural axis abnormalities in patients with thoracolumbar or lumbar scoliosis.

Curve pattern was another valuable predictor for neural axis abnormalities [27]. Since most thoracic curves were right-sided, left thoracic curves were termed as atypical curves. The presence of atypical curve was often associated with the existence of neural axis abnormalities [13, 22].

Table 2 Summary of incidences of neural axis abnormalities in presumed idiopathic scoliosis by curve pattern and age

Study	Curve pattern	Age	Incidence (%)
Pahys [21]	Mixed	1–34 months	13
Benli [16]	Right thoracic curve	>10 years	6.7
Wu [13]	Left thoracic curve	7–24 years	54
Inoue [28]	Mixed	Adolescent	18
Richards [23]	Right thoracic curve	10–18 years	6.8
Diab [19]	Mixed	8–18 years	4.2
Hausmann [22]	Left thoracic curve	Adolescent	50
	Right thoracic curve	Adolescent	2
Lee [15]	Mixed	10–34 years	9
Winter [8]	Mixed	Adolescent	2.9
Current study	Right thoracolumbar/lumbar curve	8–18 years	34.6
	Left thoracolumbar/lumbar curve	8–18 years	4.1

Hausmann et al. reported a rate of 2 % neural axis abnormalities in right thoracic scoliosis and 50 % in left thoracic scoliosis. Inoue et al. [28] investigated MRIs of 250 AIS patients, and revealed an 18 % incidence of neural axis abnormalities, of which 43 % had left thoracic scoliosis. Wu et al. [13] specifically investigated the prevalence of neural axis abnormalities in 64 asymptomatic patients with left thoracic scoliosis, finding that 37 patients (54 %) had neural axis abnormalities. Richards et al. [23] surveyed 529 presumed AIS patients with Lenke 1–4 right thoracic curve patterns using MRIs, and detected neural axis abnormalities in only 6.8 % patients. However, the majority of these studies were focused on thoracic curves, and little information was available as to thoracolumbar or lumbar curves. In the present study, we specifically investigated the MRIs of presumed “idiopathic” thoracolumbar or lumbar curves, detecting neural axis abnormalities in 34.6 % patients with “idiopathic” right thoracolumbar/lumbar scoliosis, whereas only in 4.1 % patients with left curves, implying that right thoracolumbar/lumbar curves could also be termed as atypical curves, and could serve as a strong indication for neural axis abnormalities. Moreover, compared to IS patients, patients with neural axis abnormalities had higher frequencies of apical vertebrae at thoracolumbar regions (91.4 vs. 55.0 %), and longer curves (7.5 vs. 6.1). Based on these, long thoracolumbar curve could also be termed as an atypical curve, and serve as a strong indication for neural axis abnormalities (Table 2).

The magnitude of main curve and thoracic kyphosis was significantly different between groups. The Cobb angle of main curve was larger in patients with neural axis abnormalities when compared with those without (57.7° vs. 47.0°,

$P < 0.05$). Greater thoracic kyphosis ($\geq 30^\circ$) was more frequently found in those with neural axis abnormalities when compared with those without (42.9 vs. 5.4 %, $P < 0.05$). The results were similar to those in patients with main thoracic curves who had neural axis abnormalities [13, 19, 23]. It suggested that larger magnitude of main curve and hyperthoracic kyphosis could be predictors for neural axis abnormalities in patients with either main thoracic or thoracolumbar/lumbar curves. As to thoracolumbar junction kyphosis, there were no differences between the two groups lumbar lordosis, and coronal and sagittal balance, which was also consistent with those of previous studies [15].

One of the limitations of this study was its retrospective nature. Unlike prospective study, the indication for MRI is miscellaneous in a retrospective one. In order to solve this problem, a strict inclusion criteria would always be adopted, and the series included were not a consecutive one. However, this study was specifically focused on surgically treated patients, and in our hospital, all surgically treated ones received MRI, thus, the retrospective nature did not greatly influence the power of results. Another limitation was the heterogeneity of age between the two groups. The range of age in patients with neural axis abnormalities was 8–18 years, while 10–18 years in those without neural axis abnormalities. However, the patients under 10 years were not so many in neural axis abnormalities group. Moreover, the age at first presence might be itself a predictor for the existence of neural axis abnormalities.

To the best of our knowledge, this is the first study evaluating MRIs of patients with thoracolumbar or lumbar scoliosis. According to our findings, we recommend the routine use of MRI in the patients with one or more of the following characteristics: right curves, long curve span, apex at thoracolumbar spine and hyperthoracic kyphosis.

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Conflict of interest We declare that we have no conflict of interest.

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