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ORIGINAL ARTICLE

The correlation between coronal balance and neuroaxial abnormalities detected on MRI in adolescent idiopathic scoliosis

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Abstract
Introduction The indications for magnetic resonance imaging in presumed adolescent idiopathic scoliosis (AIS) have not been established, with some studies suggesting that rates of spinal cord abnormalities are low and question the use of the routine MRI in AIS.
Objective Given the restraints on MRI resources the authors performed a retrospective audit to see if the presence of coronal or sagittal misbalance–balance could be used as a surrogate marker for the presence of spinal cord abnormalities in this patient group and hence reduce the need for unnecessary MRI scans.
Methods We performed a retrospective review of imaging of patients with AIS at our centre over a 2-year-period. All MRI scans were reported by the senior author and the presence of spinal cord abnormalities noted. All plain films were assessed by a senior SpR and ST2 orthopaedic surgeons for Cobb angle, coronal balance, sagittal balance and Lenke classification.
Results A total of 171 patients were identified with AIS. Of these, a total of 15 patients (9%) were found to have neural axis anomalies on MRI including syringomyelia, Chiari malformations and dural ectasia. The average Cobb angle was 44.9° with coronal balance varying from 67.2 mm left to 40.2 mm right. Sagittal balance varied from 125 mm negative to 83 mm positive. No correlation was found between coronal/sagittal misbalance and the presence of neural axis anomalies.
Conclusions Our audit demonstrates that neither coronal nor sagittal misbalance should be used as an indicator of neural axis abnormalities.

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Introduction

Unlike infantile and juvenile idiopathic scoliosis [1–4], the indications for magnetic resonance imaging (MRI) for adolescent idiopathic scoliosis (AIS) have not been fully established. Some studies [5, 6] have suggested that rates of spinal cord abnormality are low and findings are often insignificant, and question the use of the routine MRI in AIS. This is particularly pertinent in those institutions where resources are limited and there is an increasing call for rationalisation. In fact, the key question is which cases of AIS are truly idiopathic and what clinical features can provide an indication of underlying intraspinal pathology. Syrinx, Chiari I malformation, astrocytomas and neurofibromas have all been reported in many scoliosis cases which were thought to be idiopathic [1, 7–11]. Scoliosis with syringomyelia has been associated with a left sided curve [12], absence or abnormality of superficial abdominal reflexes [13, 14], juvenile onset, sympathetic disturbance, rapid curve progression, abnormal neurological signs and absence of apical lordotic deformity [15–20].

Whilst Benli [21] has commented that MRI abnormalities are more common in Lenke Type IC curves with back pain, no study has specifically looked at the correlation between coronal balance and the presence of neuroaxial abnormalities on MRI. Given that our hospital faces the need for rationalisation of MRI usage, the authors embarked on an audit of the institution's MRI scans to see if the degree of coronal/sagittal balance could be used as a

marker for the presence of spinal cord abnormalities in patients with adolescent idiopathic scoliosis.

Methods

A retrospective review was performed on a continuous series of pre-operative whole spine MRI studies of patients with adolescent idiopathic scoliosis referred to a specialist tertiary referral centre (Royal National Orthopaedic Hospital NHS Trust, Stanmore) for the management of scoliosis and complex spinal deformities, reported by the senior author between February 2007 and July 2009. MRI studies were performed at 1.5 T field strength with the whole spine imaged from the foramen magnum to the sacrum using a combination of sagittal, axial and coronal T1-weighted spin echo (W SE) and T2-weighted fast spin echo (W FSE) sequences. Any neuroaxial abnormalities on MRI were recorded including the presence of a syrinx and Chiari I malformation.

All patients underwent erect whole spine plain radiographs (AP and lateral). Data parameters extracted from the plain radiographs included sagittal and coronal balance, Lenke classification and Cobb angles. Standardised methods were used to determine coronal and sagittal balance, with coronal balance calculated by drawing a plumbline from the centre of the C7 vertebra and recording the amount of deviation from the midline of the sacrum. Similarly sagittal balance was measured by drawing a plumbline from the centre of C7 and recording the perpendicular distance from the posterior corner of the sacrum. All plain films were assessed independently by a senior specialist registrar and ST2 orthopaedic surgeon. Any disputes were resolved by discussion between the authors.

The presence and type of anomaly on MRI was correlated with coronal and sagittal balance as well as the curve characteristics. Normal coronal or sagittal balance was defined as less than 20 mm from the plumbline. A 2-tail *t* test was utilised to assess the significance of any differences in age and Cobb angle whilst odds ratios were used to assess differences in categorical variables. For all statistical analyses, significance was set at $p < 0.05$. Our institution does not require ethics approval or informed patient consent for retrospective audit.

Results

A total of 171 consecutive patients were included in the study, of which 137 were female and 34 male. Patients presented over a 29-month-period, with an average age at the time of MRI of 16.2 years (range 10–34 years). 23 patients were late presenting AIS aged between 20 and 34 years of age. The average Cobb angle was 44.9° (12.3–109.5°). Coronal misbalance ranged from 67.2 mm left to 40.2 mm right, with 68 patients having normal balance (<20 mm from the plumbline) and 103 patients having abnormal balance (≥20 mm from the plumbline). Sagittal balance varied from 125 mm negative to 83 positive, with 46 patients having normal sagittal balance (<20 mm from the plumbline) and 125 having abnormal sagittal balance (≥20 mm from the plumbline) (Tables 1, 2, 3). The majority of patients had a Lenke Type 1 curve (85 out of 171 patients) (Tables 4, 5, 6).

Neuroaxial abnormalities were identified in 15 patients (9%). A syrinx was present in eight patients and a Chiari Type 1 malformation in five patients. Four out of the five patients with a Chiari malformation also had a co-existent

Table 1 Patient characteristics

	Age (years)	Cobb angle (degrees)
Whole cohort	16.20	44.92
All abnormalities	15.45	45.97
Chiari	15.79	45.58
Syrinx	15.80	38.95
Chiari and syrinx	14.91	45.28

Table 2 Coronal balance and MRI abnormalities

	MRI normal	MRI abnormal	Chiari	Syrinx
No coronal misbalance	93	10	4	6
Coronal misbalance	63	5	1	2
Total	156	15	5	8

Table 3 Sagittal balance and MRI abnormalities

	MRI normal	MRI abnormal	Chiari	Syrinx
No sagittal misbalance	41	5	1	3
Sagittal misbalance	115	10	4	5
Total	156	15	5	8

Table 4 Lenke curves and neuroaxial abnormalities

Lenke class	1	2	3	4	5	6
Chiari	3	0	1	0	1	0
Syrinx	5	0	0	1	2	0
No Chiari/Syrinx	80	14	15	3	38	12
Total	85	14	16	4	40	12

Table 5 Lenke curves and neuroaxial abnormalities

Lenke ±	+	*N*	−
Chiari	1	3	1
Syrinx	1	6	1
Normal	12	136	14
Total	13	142	16

Table 6 Lenke curves and neuroaxial abnormalities

Lenke ABC	A	B	C
Chiari	1	1	3
Syrinx	1	3	4
Normal	45	39	78
Total	46	42	83

syrinx. Other neuroaxial abnormalities included dural ectasia (one in the sacrum and one in the thoracic region). A further two patients demonstrated tiny cysts in the cervical region but not causing cord expansion. Two other patients had mild dilatation of the central canal of the cord in the thoracic region, but not severe enough to be labelled a syrinx. 20 out of 171 patients also showed evidence of disc degeneration (the majority being at L5/S1 and L4/5).

Amongst the 34 male patients, there were 7 patients (21% in male group versus 6% in the female group) with abnormalities (2 Chiari malformations and 2 syrinxes (1 patient with both), 2 with dural ectasia and 2 with cysts).

When compared to the population with no neuroxial abnormalities, we found no differences in age (15.45 years; $p = 0.51$), Lenke classification or Cobb angle (47.0°; $p = 0.70$). Of these 15 patients, only 5 demonstrated coronal misbalance (odds ratio 1.35; confidence interval 0.44–4.15) and 10 had sagittal misbalance (odds ratio 1.40; confidence interval 0.45–4.35). 10% of right sided curves showed evidence of neuroaxial abnormalities compared with 8% of left sided curves (odds ratio 0.78; 95% confidence interval 0.26–2.31). 4 patients demonstrated positive sagittal balance greater than 20 mm and thoracic hyperkyphosis (Lenke modifier C) but none showed any evidence of neuroaxial abnormalities.

Subgroup analysis of the 23 late-presenting AIS population revealed no neuroaxial anomalies with an average Cobb angle of 36.6°. 10 of these 23 showed coronal misbalance and 19 had sagittal misbalance.

Chiari malformation

A Chiari Type 1 malformation was detected in five patients with one showing coronal misbalance and four demonstrating sagittal misbalance. We failed to demonstrate a significant difference between either coronal misbalance (odds ratio 0.37; confidence interval 0.04–3.38) or sagittal misbalance (odds ratio 1.49; confidence interval 0.16–13.67) and the rest of the patient population. This was also true in those four patients who also had a concurrent syrinx (coronal misbalance odds ratio of 0.50; confidence interval 0.05–4.88 and sagittal balance odds ratio of 1.11; confidence interval 0.11–10.91). There was also no difference with regard to Lenke classification, average Cobb angle (45.6°; $p = 0.95$) or age (15.79 years; $p = 0.83$).

In terms of the direction of the curve, 2% of right sided curves were associated with a Chiari malformation compared with 4% of left sided curves (odds ratio 2.17; 95% confidence interval 0.23–19.93). Only one of the five patients showed evidence of disc degeneration (odds ratio 4.4; 95% confidence interval 0.05–4.98).

Syrinx

Once again there were no differences with regard to Lenke Classification, average Cobb angle (32.1°; $p = 0.11$) or age (15.4 years; $p = 0.60$). Two patients displayed coronal misbalance (odds ratio 0.49; confidence interval 0.10–3.38) and five patients sagittal misbalance (odds ratio 0.60; confidence interval 0.14–2.61).

In terms of the direction of the curve, 2% of right sided curves were associated with a Chiari malformation compared with 7% of left sided curves (odds ratio 3.99; 95% confidence interval 0.48–33.26). Three of the eight patients showed evidence of disc degeneration (odds ratio 0.22; 95% confidence interval 0.05–0.99).

Discussion

The need for MRI in all cases of AIS remains controversial and whilst many authors [1, 7–20] have identified characteristics (left sided curve, absence or abnormality of superficial abdominal reflexes, juvenile onset, sympathetic disturbance, rapid curve progression, abnormal neurological signs and absence of apical lordotic deformity), no study has looked closely at the relationship with coronal balance.

We report a 9% prevalence of central nervous system abnormalities amongst our cohort of patients. This is perhaps higher than the 2–4% range in most other studies [5, 6]. However, Rajasekaran [11] reported an incidence of 14% amongst his 79 patients with AIS whilst Inoue [22] has reported the highest incidence of 18% amongst a cohort of 250 patients. The increased prevalence of neuroaxial abnormalities amongst our male patients (21 vs. 6% in our female group) is a common theme that is seen in these studies too.

The only study which has commented on the degree of balance and neuroaxial abnormalities is Benli [21], who

studied 104 patients with Lenke Type 1 curves, 55 of whom had AIS. Whilst none of their AIS patients demonstrated any abnormalities, 45% of their patients with juvenile scoliosis, type 1C curves and back pain had MRI abnormalities. Our study, looking purely at AIS, was unable to demonstrate any correlation between coronal or sagittal balance and the incidence of MRI abnormalities.

The clinical significance of syringomyelia or Chiari malformations without accompanying neurologic deficits is not fully understood. In fact one could argue that if there is no danger in operating on patients with these abnormalities, then there is no need for pre-operative MRI screening. Indeed, Inoue [21] has argued that patients with syringomyelia and Chiari malformations have little risk of developing complications as a result of scoliosis surgery. However, this is not a view held by other authors. Syringomyelia may be a risk factor for neurologic complication during correction of scoliosis, especially after distraction [23]. Ozerdemoglu [24] reported that 3 (8%) patients without decompression surgery for syringomyelia had a significant deficit after corrective surgery for scoliosis. Tokunaga [25] also demonstrated that the frequency of neurologic complications in scoliosis surgery was 14% in patients presenting with scoliosis associated with syringomyelia and that it increased to 33% in patients who had not been treated for syringomyelia.

Not all the patients in this series underwent surgery but all cases that do undergo correction have intraoperative spinal cord monitoring. We agree with Tokunaga that those patients with neuroaxial abnormalities are a very high risk group and should have intraoperative evoked potentials during surgery.

Whilst the authors acknowledge that this is a retrospective study, our findings are not out of line with some prospective studies [5, 7, 20]. In conclusion, magnetic resonance imaging may be beneficial for patients with presumed adolescent idiopathic scoliosis even in the absence of neurological findings to determine any neural axis abnormality, and it may be helpful in decision making in the surgical treatment of AIS. However, the presence or absence of coronal or sagittal misbalance does not appear to be an indicator of underlying central nervous system abnormalities, and it is impossible to rationalise the use of MRI resources using misbalance as an exclusion criteria.

Conflict of interest None.

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