

Incidence and significance of findings on spinal MRIs in a paediatric population with spinal column complaints

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Abstract

Purpose We sought to identify correlations between working diagnosis, surgeon indication for obtaining spinal MRI and positive MRI findings in paediatric patients presenting with spinal disorders or complaints.

Methods Surgeons recorded their primary indication for ordering a spinal MRI in 385 consecutive patients. We compared radiologist-reported positive MRI findings with surgeon response, indication, working diagnosis and patient demographics.

Results The most common surgeon-stated indications were pain (70) and coronal curve characteristics (63). Radiologists reported 137 (36%) normal and 248 (64%) abnormal MRIs. In total, 58% of abnormal reports (145) did not elicit a therapeutic or investigative response, which we characterized as 'clinically inconsequential'. In all, 42 of 268 (16%) presumed idiopathic scoliosis patients had intradural pathology noted on MRI.

Younger age (10.3 years *versus* 12.0 years) was the only significant demographic difference between patients with or without intradural pathology. Surgeon indication 'curve magnitude at presentation' was associated with intradural abnormality identification. However, average Cobb angles between patients with or without an intradural abnormality was not significantly different (39° *versus* 37°, respectively). Back pain without neurological signs or symptoms was a negative predictor of intradural pathology.

Conclusion Radiologists reported a high frequency of abnormalities on MRI (64%), but 58% of those were deemed clinically inconsequential. Patients with MRI abnormalities were

two years' younger than those with a normal or inconsequential MRI. 'Curve magnitude at presentation' in presumed idiopathic scoliosis patients was the only predictor of intrathecal pathology. 'Pain' was the only indication significantly associated with clinically inconsequential findings on MRI.

Level of Evidence: III

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Introduction

Paediatric orthopaedic surgeons are frequently consulted to evaluate children and adolescents for evidence of spinal deformity and/or complaints of back pain. Between 1% to 4% of school-age children screen positively for potential scoliosis^{1,2} and 32% of patients with presumed adolescent idiopathic scoliosis have associated complaint of back pain.³ One survey in children and adolescents identified found that 74% complained of back pain at some point.⁴ As healthcare has shifted to more specialized care, the responsibility has fallen on the paediatric orthopaedic surgeon to evaluate these presenting complaints, and determine what further investigations are warranted after careful history-taking and clinical examination. As costs rise and resources become scarce, devising new and more accurate screening protocols has become all the more necessary and daunting. Technology has dramatically changed the tools at a physician's disposal; most notably, the emergence of MRI as a common diagnostic tool. Patients with back pathology or symptomology are prime candidates to be referred for an MRI evaluation of the spine. However, MRIs are expensive, may have limited availability in some settings, may require sedation or anaesthesia in younger or anxious patients and are not entirely without risk.

While there is general agreement that spinal MRI is not required for all patients with spinal deformity or symptoms,⁵⁻¹⁰ some authors recommend spinal MRI for all patients undergoing spinal fusion for example.¹¹⁻¹⁷ Specific

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demographic and/or morphological features in patients with scoliosis are noted to be associated with a higher incidence of intrathecal abnormality (most notably, Arnold-Chiari malformation and/or syringomyelia), and obtaining spinal MRI in such scenarios is less controversial, although neither universally accepted, nor pathognomonic for spinal cord abnormality.^{8,18} These features include younger age at presentation,^{8,12,14-17} left-sided juvenile or adolescent thoracic scoliosis,¹¹ particularly in male patients,^{11,12,14,16,17} absent thoracic lordosis in thoracic curves,¹⁹ increased thoracic kyphosis^{7,8,12,16} and absent abdominal reflexes.¹⁴

In this study, we sought to prospectively quantify and qualify the reasons paediatric orthopaedic surgeons requested a spinal MRI prior to its acquisition in the context of an outpatient setting where the surgeon is charged with evaluating paediatric patients with spinal complaints and/or pathology; to characterize and quantify all abnormalities reported by the paediatric radiologists on spinal MRI; and to identify correlations between paediatric orthopaedic surgeons' indications for obtaining a spinal MRI, patients' working diagnosis and abnormality noted on MRI.

Materials and methods

With institutional review board approval, prospectively collected clinical and radiographic data of paediatric patients with spinal pathology and/or symptomatology who underwent a full spinal MRI ordered by an orthopaedic surgeon between 2009 and 2011 was reviewed for this analysis. This study included patients aged 0 years to 18 years with no history of spinal or neurosurgery. Patients with known neuromuscular or congenital scoliosis were excluded for this review, as well as patients referred for a spinal MRI by anyone other than one of the full-time attending paediatric orthopaedic surgeons at our institution. Patients with a previous spinal MRI, or an incomplete or lumbar spinal MRI, were also excluded.

At the time of ordering the spinal MRI, the treating surgeon was asked to document the specific reason(s) for requesting the study from a list of 14 indications. Surgeons were allowed to document more than one indication, in which case they were asked to rank them in order of relevance/priority. Only the primary indications were used for analysis in this review.

Clinical and radiographic data collected included working diagnosis at the time of ordering the MRI, comorbidities, height, weight, patient complaints of pain and radiographic measures. Original data was collected prospectively and then reviewed and verified retrospectively.

The study team categorized spinal MRIs as abnormal (intradural, extradural, vertebral and/or incidental findings) or normal based on radiologist reported findings.

Radiologist-reported findings that did not elicit a therapeutic or investigative response, the study team characterized as 'clinically inconsequential'. Patient diagnosis, demographics, clinical data and physicians' primary indications were correlated to the presence or absence of consequential MRI findings.

Statistical analysis

In the initial statistical analysis, continuous variables, such as Cobb angles, height and weight, were first examined for normality and equal variance. Averages of continuous variables were computed based on groups and then analyzed. The non-parametric Mann-Whitney U test was used when comparing two groups (i.e. intradural abnormality group *versus* no intradural abnormality group). A Pearson's correlation was used when calculating the association between pairs of variables within each group.

Results

A total of 385 patients met the inclusion criteria. Demographic characteristics are summarized in Table 1. There were 271 female and 114 male cases. The mean age at time of MRI was 11.9 years (0.3 to 18.1). The working diagnoses at the time of MRI request included presumed idiopathic scoliosis in 268 (69.6%; including 195 adolescent, 61 juvenile and 12 infantile scoliosis), 67 (17.4%) without spinal deformity diagnosis, 27 (7%) with non-idiopathic scoliosis and seven (1.8%) with spondylolysis or spondylolisthesis. In all, 315 patients had a measurable coronal

Table 1 Overall cohort demographics (n = 385)

Demographic	n (%/range)
Sex	
Female	271 (70.4)
Male	114 (29.6)
Age, yrs	11.91 (0.3 to 18.1)
Working diagnosis	
Idiopathic scoliosis	268 (69.6)
Adolescent idiopathic scoliosis	195
Juvenile idiopathic scoliosis	61
Infantile idiopathic scoliosis	12
No spinal diagnosis*	67 (17.4)
Lower limb deformity**	31
Primary diagnosis of back pain	26
Multiple hereditary exostoses	5
Torticollis	2
Neurofibromatosis	1
Achondroplasia	1
Hip/knee flexion contracture	1
Spinal asymmetry	16 (4.2)
Kyphoscoliosis	9 (2.3)
Kyphosis	7 (1.8)
Spondylolysis and/or spondylolisthesis	7 (1.8)
Syndromic scoliosis	6 (1.6)
Unspecified scoliosis	5 (1.3)

*'No spinal diagnosis' implies a coronal plane curvature less than 10° on spinal radiographs, without other evident abnormality

**eight clubfeet, seven cavovarus feet, seven toe walkers, nine others

Table 2 Radiologist-reported MRI abnormalities overview (n = 385 patients)

Abnormality classification/type	Total	Consequential finding
Intradural cord abnormalities		
Chiari	9	9
Chiari with associated syringomyelia	17	17
Mega cisterna magna	7	3
Myelomalacia	2	2
Syringomyelia	8	8
Tethered cord/lipoma	16	14
Tethered cord/tight filum	10	6
Tumour	2	2
Extradural cord abnormalities		
Stenosis	16	4
Tumour	3	3
Vertebral abnormalities		
Disc herniation with compression	15	5
Disc herniation without compression	61	9
Congenital abnormalities	4	0
Facet abnormalities	68	2
Schmorl's nodes	31	2
Incidental findings	133	17
Total radiologist-reported findings	402	103

curve, with a mean of 39° (7° to 147°) while 70 patients either did not have a scoliosis film or a measurable curve. A complaint of back pain was recorded in 189/385 patients, including 131/256 patients with presumed juvenile or adolescent idiopathic scoliosis. The only demographic characteristic significantly different between patients with or without intradural findings on MRI was younger age in the former (10.3 years *versus* 12.0 years).

Radiologists reported a total of 420 abnormal findings in 248/385 patients (64.4%). We characterized radiologist-reported abnormalities as 'consequential' if there was any therapeutic or investigative response by the treating surgeon, and 'inconsequential' if there was no

such response. Radiologist-reported MRI abnormality was deemed clinically consequential in only 103/248 patients (42%) and inconsequential in 145 (58%). These abnormalities, ranging from incidental to intradural findings, are summarized in Table 2. Intradural abnormalities were noted in 61 patients (25% of total abnormal MRIs and 16% of the total patient population).

In total, 42 (15.7%) of 268 patients with a working diagnosis of idiopathic scoliosis had intradural abnormalities identified on MRI. These diagnoses included seven Chiari malformations, 16 syringomyelia with an associated Chiari malformation, seven syringomyelia without an associated Chiari malformation, 11 filum terminale abnormalities (eight lipomas and three tight filum terminale) and one myelomalacia.

The 14 surgeon-stated primary indications, their frequency and association with clinically consequential MRI findings are summarized in Tables 3 and 4. The most common primary indication was 'pain' (70 patients, 18%) followed by 'coronal curve characteristics' (63 patients, 16%). Of the 70 patients whose primary indication for spinal MRI was 'pain', 20 were normal while 50 had radiologist-reported abnormalities. However, only 18 of those 50 were deemed clinically consequential: 14 underwent some form of pain management and four had intradural abnormalities (two lipomas, one each Chiari and spinal cord tumor). 'Pain' as a primary indication was the only surgeon-stated indication negatively associated with a clinically consequential intradural MRI finding (p = 0.015). 'Curve magnitude at presentation' was listed as the primary indication in 16 patients (4%); six of these had clinically consequential abnormalities on spinal MRI. 'Curve magnitude at presentation' was the only primary

Table 3 Surgeon-reported indication for spinal MRI

	All diagnoses (n = 385)	AIS (n = 195)	JIS/IIS(n = 73)	Other diagnoses (n = 117)
Primary indication for MRI				
Pain	70	31	3	36
Coronal curve characteristics	63	54	4	5
Associated diagnosis	54	9	2	43
Sagittal curve characteristics	53	38	7	8
Age at presentation	53	5	48	0
Abnormal motor sensory	21	7	1	13
Preoperative	19	13	5	1
Curve magnitude at presentation	16	15	1	0
Other	12	6	0	6
Rapid curve progression	10	9	1	0
Abnormal abdominal reflexes	9	7	1	1
Parental anxiety/insistence	2	0	0	2
Congenital scoliosis*	2	1	0	1
Sacral dimple	1	0	0	1
Radiologist report				
Normal	137	72	29	36
Abnormal	248	123	44	81
Clinically consequential finding	103	48	19	36
Consequential intradural finding	61	27	15	19

*an indication of congenital scoliosis was chosen by the treating physician if there was no confirmed diagnosis of a vertebral anomaly prior to the MRI, but the physician suspected congenital factors in the patients' abnormal curvature
 AIS, adolescent idiopathic scoliosis; JIS, juvenile idiopathic scoliosis; IIS, infantile idiopathic scoliosis

Table 4 Primary indications and consequential intradural findings (n = 385)

Primary indication	Total patients with primary indication	Patients with consequential intradural finding	p-value*
Pain**	66	4	0.010
Coronal curve characteristics	52	11	0.701
Associated diagnosis	43	8	0.823
Sagittal curve characteristics	42	11	0.292
Age at presentation	43	9	0.807
Abnormal motor sensory	16	4	0.757
Preoperative	18	1	0.332
Curve magnitude at presentation***	10	6	0.015
Other	10	3	0.414
Rapid curve progression	10	0	0.374
Abnormal abdominal reflexes	7	2	0.639
Parental anxiety/insistence	2	0	> 0.999
Congenital scoliosis****	1	1	0.292
Sacral dimple	0	1	0.158

*Chi-Square test used for statistical analysis

**R-value is negative for 'Pain', indicating a correlation to an MRI without intradural findings

***R-value is positive for 'Curve Magnitude at Presentation', indicating a correlation to an MRI with intradural findings

****An indication of congenital scoliosis was chosen by the treating physician if there was no confirmed diagnosis of a vertebral anomaly prior to the MRI, but the physician suspected congenital factors in the patients' abnormal curvature

indication positively associated with a clinically consequential MRI finding ($p = 0.03$). The mean major coronal plane deformity Cobb angle in those 16 patients was 73° (48° to 107°), compared with 35° (7° to 147°) in the cohort with scoliosis as a whole ($p < 0.01$). However, the scoliosis Cobb angle in the 42 patients with presumed idiopathic scoliosis who had intradural abnormality on spinal MRI (mean 40° ; 14° to 107°) was not statistically significantly different than those without intradural abnormality (mean 40° , 7° to 147°) ($p = 0.31$).

The absence of apical thoracic lordosis as visualized by examining the posterior margins of the concave ribs on lateral radiographs of patients with presumed idiopathic thoracic scoliosis has been associated with syringomyelia and a relative indication for obtaining spinal MRI.¹⁹ We evaluated all available lateral radiographs of patients with a working diagnosis of idiopathic thoracic or thoracolumbar scoliosis for the presence of apical lordosis demonstrated in the contour of the concave posterior rib margins at the apex of coronal plane deformity.¹⁹ Of 223 eligible patients, 115 had radiographic apical lordosis, while 108 had not or were indeterminate. Patients with apical lordosis had significantly larger maximum Cobb angles than those who had no apical lordosis (49° compared with 34°). The absence of apical lordosis was statistically significantly correlated with clinically consequential cord findings, including Chiari malformation and/or syringomyelia ($p < 0.01$). However, the R-value was -0.22 , indicative of a weak relationship. These findings are summarized in Table 5.

Table 5 Apical lordosis and Chiari and/or syringomyelia in patients with a working diagnosis of idiopathic scoliosis (n = 223)*

Apical lordosis	Chiari and/or syringomyelia		p-value**	R-value
	Negative, n (%)	Positive, n (%)		
Absent indeterminate	85 (79)	23 (21)	< 0.01	- 0.22
Present	108 (94)	7 (6)		

*45/268 patients were excluded from this analysis: three without a lateral film and 42 without a thoracic or thoracolumbar curve

**Chi-square test used for statistical analysis

Discussion

Our study was unique in that rather than identifying a cohort of patients with a particular diagnosis (such as presumed idiopathic scoliosis), we sought to determine in a prospective way why surgeons charged with evaluating paediatric patients with spinal complaints and/or deformity in an academic paediatric orthopaedic hospital-based group practice requested a spinal MRI. The working diagnoses of the cohort were thus heterogeneous, including primarily presumptive idiopathic scoliosis, but also Scheuermann's kyphosis, spinal asymmetry, back pain without true scoliosis and spondylolysis/lithesis. We sought to identify any demographic and/or morphological features that were predictive of a positive MRI, in order to further clarify when spinal MRI was indicated, or not. Finally, we sought to evaluate and qualify the clinical significance of reports of abnormalities provided by paediatric radiologists.

Indications for spinal MRI in the paediatric population is controversial in many clinical scenarios. Authors have recommended both for^{6,11-17} and against^{5,7,8,10} routine MRI of patients with presumptive idiopathic scoliosis as part of their pre-surgical evaluation. The incidence of intrathecal anomalies, specifically, Chiari malformation, syringomyelia or both in series of patients with presumptive idiopathic scoliosis vary from $< 2\%$ ¹⁰ to 28% .¹⁸ Certain demographic and/or morphological features have been noted to be associated with a higher likelihood of intrathecal abnormality on MRI, including but not limited to left-sided thoracic adolescent or juvenile scoliosis,¹¹ infantile scoliosis,²⁰ male sex,^{11,12,14,16,17} atypical sagittal contour^{7,8,12,16,19} and associated neurological findings (such as asymmetric abdominal reflexes).¹⁴ None of these features is pathognomonic for intrathecal abnormality, however, and the precise indications for MRI in presumptive idiopathic scoliosis remains controversial and unclear. A MRI-identified intradural abnormality of nearly 16% in our presumed idiopathic scoliosis we believe is due to 'selection bias', since this study was not a serial sampling of patients with that diagnosis. Since no patient/radiographic characteristic was considered an absolute indication in our patient cohort, we cannot make reliable comparisons between

our study and others with respect to the incidence of abnormalities on spinal MRI.

We learned several things from this study. Firstly, there were no specific demographic and/or morphological features of the patient population that lend themselves to our making strong recommendations with respect to who should have or does not need a spinal MRI in the absence of clear neurological deficit. Secondly, the only surgeon-stated indication for spinal MRI positively associated with identification of intrathecal abnormality was 'curve magnitude at presentation'. In the 16 such cases, the Cobb angle deformity was significantly larger than the cohort as a whole. However, the Cobb angle in the subset of scoliosis patients with or without intrathecal abnormality was approximately the same. Therefore, we cannot recommend a threshold of deformity above which spinal MRI is warranted. More likely, the surgeon indication of 'curve magnitude at presentation' was the experienced surgeons' instinctive sense that a particular patient's clinical characteristics were not in keeping with a diagnosis of idiopathic scoliosis. These characteristics include disproportionate deformity for age, and/or unusual radiographic characteristics, such as increased kyphosis. Thirdly, patients with pain as the primary complaint/indication for MRI in the absence of specific neurological complaint or finding were the most likely to have a normal MRI. We can, therefore, say that based on this population, both surgeon and parent/patient should be aware that spinal MRI is unlikely to reveal the aetiology of pain symptoms and conduct themselves accordingly. Finally, radiologists frequently report abnormalities on MRI that are routinely ignored by the treating surgeon or deemed clinically inconsequential (58% of reported abnormalities in our cohort). This clinical reality has been noted by others,^{6,9,15,21} including the lack of correlation between reported facet abnormality/effusion, in the absence of supporting clinical manipulative challenge of the abnormal region.^{22,23} Therefore, treating surgeons should be aware, and patient/families educated to the likelihood of clinically inconsequential abnormalities in radiologists' formal reports of these studies. This is of increasing relevance as families more regularly gain direct access to radiologist reports through 'patient portals'.

This study has several limitations. The most important in our view is the fact that the primary inclusion criterion was the ordering of a spinal MRI by a paediatric orthopaedic surgeon, rather than a prospective enrolment of patients with a specific diagnosis or complaint. Thus, we cannot make reasonable estimations of the incidence of MRI abnormalities by particular diagnosis, since we do not have an accurate estimation of denominators for those sundry diagnoses. Secondly, indications such as 'curve size', 'curve characteristics' and the like were not quantified; these were subjective responses by the treating surgeon.

Thirdly, while we defined 'inconsequential abnormalities' as those that did not trigger a response by the treating surgeon, we have not conducted a longitudinal study to confirm that abnormalities (such as disk protrusion or small syrinx) did not become consequential at some point in the future. Additionally, we characterized MRI abnormalities reported as 'inconsequential' in patients with complaints of back pain, based on the absence of a therapeutic response by the treating surgeon, rather than any other method of confirming or refuting that abnormality (such as disk protrusion without neural element compression) as the cause of a patient's pain. Finally, our data did not allow us to determine whether multiple surgeon-specified indications could increase or decrease the likelihood of an abnormal spinal MRI.

In conclusion, in this cross-section of patients, the most important indicator of MRI abnormality was a sense that 'something was not right', evidenced by such patients being younger and having larger deformities. In that context, attending physicians should trust their instincts as much as any specific demographic or radiographic characteristic in deciding whether paediatric patients warrant undergoing spinal MRI for spinal deformity and/or symptoms. Pain was the least-useful predictor of abnormal spinal MRI in this cohort.

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ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the host institutional review board.

Informed consent: Participants of this study were consented with institutional standard informed consent procedures in compliance with Good Clinical Practice (GCP) requirements. Informed Consent documents were reviewed and approved by the host institutional review board prior to enrollment of subjects.

ICMJE CONFLICT OF INTEREST STATEMENT

JGB reports royalties from sales of a circular external fixator from Orthofix, outside the submitted work.

The other authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

KR: Conceived, designed and supervised the study, Contributed to manuscript preparation.

RJD: Acquired and analyzed all data from the study, Reviewed all data, Drafted the manuscript.

DCT: Acquired and analyzed all data from the study, Reviewed all data, Drafted the manuscript.

AK: Acquired and analyzed all data from the study.

JGB: Reviewed all data, Drafted the manuscript.

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