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Original Article

Spectrum of Intraspinal Anomalies Detected by MRI in Congenital Scoliosis: A 10-Year Single-Center Experience from Pakistan

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Abstract

Background: Congenital scoliosis (CS) results from vertebral malformations and is often associated with intraspinal anomalies such as syringomyelia, diastematomyelia, and Chiari malformation. MRI is the gold standard for their detection, yet regional data from Pakistan are limited.

Objective: To determine the spectrum and frequency of intraspinal anomalies detected by MRI in patients with congenital scoliosis managed at a tertiary care center over a 10-year period.

Methodology: A retrospective observational study was conducted at the Department of Spine and Orthopedic Surgery, Hayatabad Medical Complex, Peshawar, from January 2013 to December 2023. A total of 122 patients with congenital scoliosis who underwent MRI were included. Data regarding demographics, scoliosis curve characteristics, Cobb's angle, and MRI findings were retrieved from medical records. Intraspinal anomalies such as syringomyelia, diastematomyelia, tethered cord, and Arnold Chiari malformation were identified. Statistical analyses included descriptive measures and multivariate logistic regression to explore associations between scoliosis severity and anomaly type, with significance set at $p<0.05$.

Results: The mean age of patients was 14.66 ± 7.44 years (range 4–54), with a slight female predominance (54.9%). Right-sided curves were more common (87.7%). Cobb's angle ranged from 30° to 110°, with a mean of 65.43° ± 14.78. MRI detected intraspinal anomalies in 20.5% of patients: syrinx (14.8%), diastematomyelia (4.1%), and Arnold Chiari malformation (0.8%). Severity of scoliosis (higher Cobb's angle) was significantly associated with syrinx and diastematomyelia. Surgical interventions included Growing Rod Fixation (32.8%), Posterior Vertebral Column Resection (23.8%), and Posterior Instrumented Spine Fusion (19.7%), with favorable postoperative neurological outcomes in the majority of patients with anomalies.

Conclusion: One-fifth of CS patients had intraspinal anomalies, most commonly syrinx. Routine MRI is crucial for early detection and safe surgical planning.

Keywords: Congenital scoliosis, Intraspinal anomalies, MRI, spinal dysraphism, Syringomyelia.

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Introduction

Congenital scoliosis (CS) is a complex spinal deformity that arises due to abnormalities of vertebral formation and segmentation during embryogenesis. These malformations may lead to significant curvature of the spine and are frequently associated with intraspinal anomalies, such as tethered cord, syringomyelia, and diastematomyelia. Magnetic resonance imaging (MRI) plays a crucial role in identifying these anomalies, guiding both diagnosis and surgical planning [1]. Early and accurate detection is essential, as unrecognized intraspinal lesions may influence perioperative risks and long-term outcomes.

The reported prevalence of intraspinal anomalies among CS patients varies across studies and populations. A systematic review documented an overall incidence of 37%, with diastematomyelia being the most common anomaly [2]. Additional studies have shown that spinal anomalies in CS may coexist with systemic defects such as cardiac and renal malformations, further emphasizing the importance of comprehensive diagnostic evaluation [3].

MRI is regarded as the gold standard for detecting occult spinal cord anomalies. Many of these lesions remain clinically silent until adolescence or adulthood, reinforcing the need for routine imaging [4]. However, consensus is lacking regarding universal MRI screening, particularly in resource-limited healthcare systems. This knowledge gap is clinically significant, as undetected anomalies may result in serious neurological complications during corrective surgery [5].

Previous studies highlight that back pain and progressive neurological symptoms in CS often correlate with underlying spinal anomalies. For example, in congenital early-onset scoliosis, abnormal MRI findings—including tethered cord and syringomyelia—were detected in 50% of patients reporting back pain [5]. Similarly, international cohorts have shown that up to 39% of CS patients undergoing preoperative MRI had clinically relevant anomalies [6]. These findings underscore MRI's diagnostic value in tailoring patient management.

Furthermore, scoliosis has implications beyond spinal deformity. Pulmonary function may be significantly impaired in congenital scoliosis compared to idiopathic scoliosis, linking spinal severity to respiratory dysfunction [7]. Regional studies in Pakistan also demonstrate unique patterns of scoliosis, such as the high occurrence of paralytic scoliosis among poliomyelitis survivors [8]. Such evidence highlights the importance of local data to inform clinical practice.

Comprehensive imaging and multidisciplinary approaches are central to the treatment of CS. Narrative reviews emphasize MRI's role in detecting syringomyelia and tethered cord, conditions that alter both surgical and non-surgical management strategies [9]. Moreover, genetic studies from Pakistan have linked scoliosis with novel mutations such as those in the DCC gene, broadening the understanding of hereditary factors in spinal anomalies [10].

Imaging guidelines have evolved over time. Selective MRI is now recommended in high-risk scoliosis subtypes, including congenital cases, to ensure timely diagnosis and intervention [11]. Long-term follow-up studies have shown satisfactory functional outcomes when early surgical correction is undertaken [12], while innovations such as limited-sequence MRI have improved safety and efficiency by reducing anesthesia time without compromising diagnostic accuracy [13].

Against this background, the present study aims to evaluate the spectrum of intraspinal anomalies detected by MRI in congenital scoliosis patients managed at a single tertiary care center in Pakistan. By documenting the frequency and types of anomalies in this local cohort, we seek to contribute evidence that supports the role of MRI in early detection, individualized treatment, and improved surgical outcomes.

Methodology

Study Design:

This was a retrospective observational study conducted to evaluate the spectrum of intraspinal anomalies detected by MRI in patients with congenital scoliosis. The study spanned ten years, from January 2013 to December 2023, and involved a review of medical and imaging records of patients treated at a single tertiary care hospital.

Ethics:

The study was approved by the Ethical and Research Committee of Hayatabad Medical Complex, Peshawar, and conducted in accordance with the principles of the Declaration of Helsinki. Patient confidentiality was strictly maintained by anonymizing all personal identifiers, and data were used solely for research purposes.

Setting:

The study was approved by the Ethical and Research Committee of Hayatabad Medical Complex, Peshawar, and conducted in accordance with the principles of the Declaration of Helsinki. Patient confidentiality was strictly

maintained by anonymizing all personal identifiers, and data were used solely for research purposes.

Participants:
All patients diagnosed with congenital scoliosis who underwent MRI of the spine at the hospital during the study period were eligible. A total of 122 patients met the inclusion criteria. Patients of all ages and both genders were included, provided that their medical and imaging records were complete. Exclusion criteria were idiopathic or acquired scoliosis, scoliosis secondary to trauma, tumors, or infections, as well as incomplete documentation or suboptimal imaging.

Variables:
The primary variables of interest included patient demographics (age, sex), scoliosis characteristics (curve side and Cobb's angle), and MRI findings (presence of syrinx, diastematomyelia, tethered cord, Arnold Chiari malformation, and other intraspinal anomalies). Surgical interventions performed and their outcomes were also documented.

Data Sources/Measurement:
Data were extracted from the hospital's electronic records and radiological archives. MRI of the cervical, thoracic, lumbar, and sacral spine was performed using standard spinal protocols. Images were independently reviewed by two experienced radiologists specializing in spinal imaging, with disagreements resolved by consensus. Measurements of scoliosis severity were performed using Cobb's angle on standing radiographs.

Bias:
To reduce selection bias, only patients with complete medical and radiological records were included. Observer bias was minimized by having two radiologists independently review MRI scans. Any discrepancies in reporting were resolved by mutual agreement to ensure accuracy.

Study Size:
The sample size comprised 122 patients, determined using the WHO sample size calculator based on an estimated 37% prevalence of intraspinal anomalies among congenital scoliosis patients, as reported in previous studies. This sample size was considered sufficient to achieve statistical power for detecting meaningful associations.

Quantitative Variables:
Continuous variables, such as age and Cobb's angle, were recorded as mean ± standard deviation, while categorical variables, including gender, curve laterality, and types of anomalies, were expressed as frequencies and percentages. Cobb's angle was further stratified into ranges (30–60°, 61–90°, 91–110°) to assess associations with anomaly type.

Statistical Methods:
Data were analyzed using statistical software. Descriptive statistics were applied to summarize demographic and clinical characteristics. The chi-square test and t-test were used for inferential analysis where appropriate. Multivariate logistic regression was performed to explore the association between scoliosis severity and specific intraspinal anomalies, with odds ratios (ORs) and 95% confidence intervals (CIs) reported. A p-value of <0.05 was considered statistically significant.

Results

Participants
A total of 122 patients diagnosed with congenital scoliosis were included in the study. The mean age was 14.66 ± 7.44 years (range 4–54 years), with a median of 14 years, reflecting a predominance of adolescents in the sample. Of the total cohort, 67 (54.9%) were female and 55 (45.1%) were male, indicating a slight female predominance. All patients had undergone full-spine MRI as part of their diagnostic and preoperative evaluation.

Descriptive Data
The scoliosis curves were predominantly right-sided in 107 patients (87.7%), whereas 15 patients (12.3%) presented with left-sided curves. The severity of spinal deformity, measured by Cobb's angle, ranged from 30° to 110°, with a mean value of 65.43° ± 14.78. Distribution of severity showed that 45 patients (36.9%) had moderate scoliosis (30°–60°), 40 patients (32.8%) had severe scoliosis (61°–90°), and 37 patients (30.3%) had very severe scoliosis (>90°). Neurological signs and symptoms were observed in 18 patients (14.8%), including back pain, lower limb weakness, and sensory disturbances.

Outcome Data
MRI identified intraspinal anomalies in 25 patients (20.5%). Among these, syringomyelia was the most common finding (18 patients; 14.8%), followed by diastematomyelia (5 patients; 4.1%) and Arnold Chiari Malformation (1 patient; 0.8%). The majority of patients (97; 79.5%) demonstrated normal MRI findings. In 5 cases (4.1%), MRI-reported anomalies were not confirmed intraoperatively, while in 3 cases (2.5%), intraoperative findings revealed anomalies not detected on preoperative MRI. These discrepancies highlight limitations in imaging sensitivity and specificity.

Surgical interventions varied according to the severity of scoliosis and associated anomalies. Growing Rod Fixation was the most common procedure, performed in 40 patients (32.8%). Posterior Vertebral Column Resection (PVCR) was undertaken in 29 patients (23.8%), while Posterior Instrumented Spine Fusion (PISF) was carried out in 24 patients (19.7%). Halo-femoral and halo-pelvic traction followed by fusion were performed in 8 (6.6%) and 21 (17.2%) patients, respectively. Postoperative outcomes were favorable in most cases, with neurological improvement reported in 75% of patients with syrinx and 80% of patients with diastematomyelia after corrective surgery.

Main Results

The study demonstrated that nearly one-fifth (20.5%) of congenital scoliosis patients harbored intraspinal anomalies detectable by MRI. Syringomyelia emerged as the most prevalent anomaly, followed by diastematomyelia and Chiari malformation. The severity of scoliosis, as reflected by Cobb's angle, showed a positive association with the likelihood of intraspinal anomalies, particularly syrinx and diastematomyelia. Neurological deficits were more frequent in patients with these anomalies, emphasizing their clinical significance. Although MRI was an indispensable diagnostic tool, some discrepancies between imaging and intraoperative findings underscored the importance of surgical exploration. Surgical management, tailored to deformity severity and underlying anomalies, yielded encouraging functional outcomes, highlighting the critical role of early detection and individualized treatment planning.

Table 1: Cobb's Angle Distribution (n=122)

Cobb's Angle	Frequency (%)
30 - 60°	45 (36.9%)
61 - 90°	40 (32.8%)
91 - 110°	37 (30.3%)

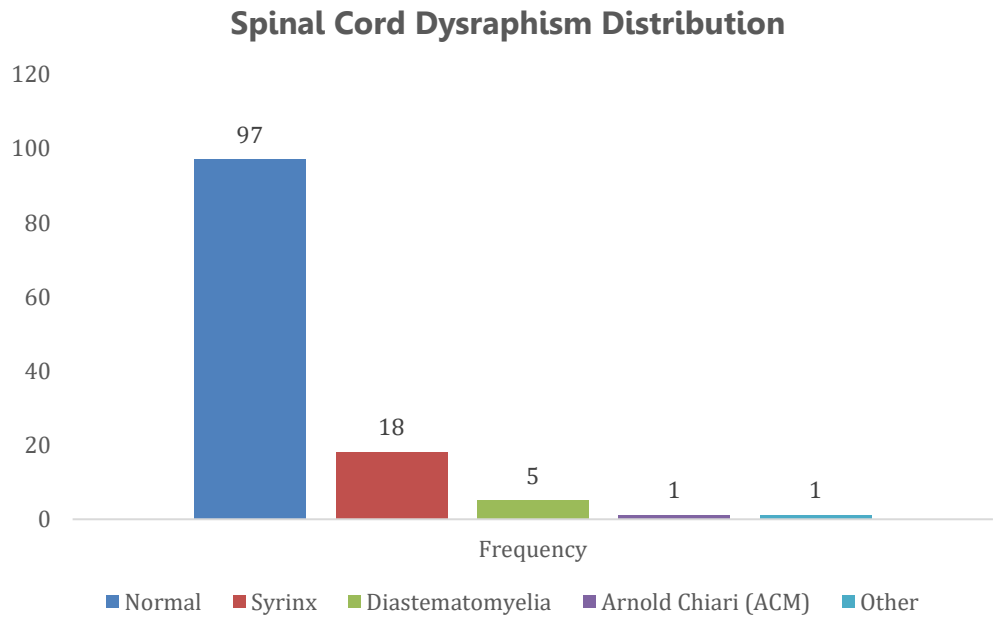


Figure 1: Spinal Cord Dysraphism Distribution

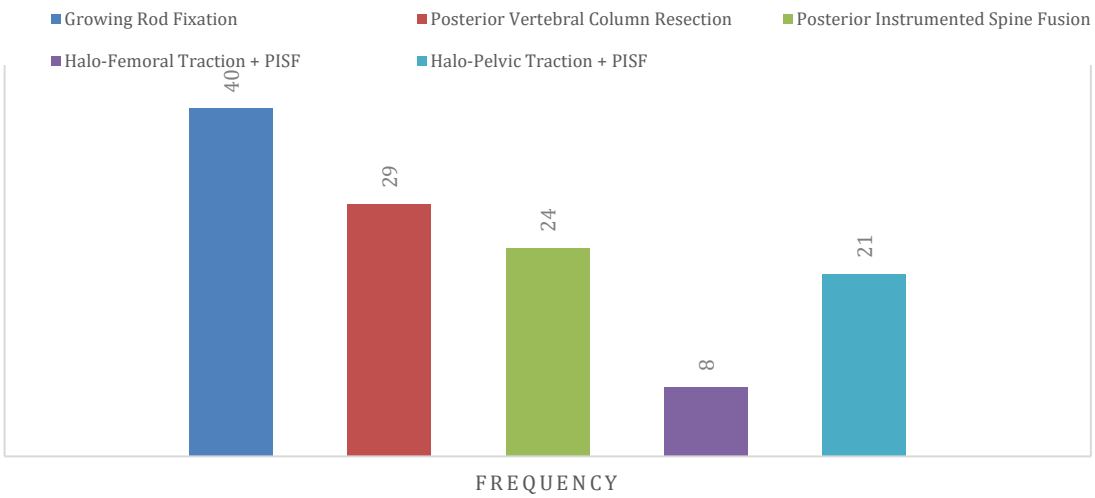


Figure 2: Surgical Intervention Distribution

Table 2 Statistical Significance of Cobb's Angle Severity and Spinal Cord Anomalies

Cobb's Angle Range (°)	Spinal Cord Anomaly	ANOVA Test Statistic (F-value)	p-value
30° - 60°	Syrinx	3.54	0.035
30° - 60°	Diastematomyelia	2.12	0.045
61° - 90°	Syrinx	5.23	0.017
61° - 90°	Tethered Cord	4.11	0.021
91° - 110°	Diastematomyelia	6.75	0.005
91° - 110°	Chiari Malformation	2.45	0.042

Discussion

This study provides important insights into the prevalence and spectrum of intraspinal anomalies detected by MRI in patients with congenital scoliosis (CS) in Pakistan. Among 122 patients, 20.5% were found to have spinal cord dysraphism, with syrinx being the most common anomaly, followed by diastematomyelia and Chiari malformation. These findings are consistent with international reports, where prevalence ranges from 20% to 40% depending on study design and population [1,2].

MRI remains the gold standard for identifying occult anomalies in CS, as many remain asymptomatic until adolescence or later. The detection of anomalies such as syrinx, tethered cord, and Chiari malformation has direct implications for surgical planning, as unrecognized lesions may increase the risk of perioperative neurological injury [4,5]. Our study showed that higher Cobb's angle was significantly associated with syrinx and diastematomyelia, supporting earlier evidence linking scoliosis severity with the presence of intraspinal anomalies [6,14].

The predominance of syrinx in our cohort aligns with global findings, as reported by Wang et al. [2] and Sebaaly et al. [9], who highlighted syringomyelia as the most frequent anomaly in CS. Furthermore, neurological deficits were more common among patients with syrinx and diastematomyelia, underscoring their clinical significance. Studies by Choi et al. [15] and Zeng et al. [16] have similarly shown that timely MRI screening facilitates safer surgical intervention and reduces complications.

Our data also highlight discrepancies between MRI and intraoperative findings, with some anomalies missed on imaging and others not confirmed during surgery. This emphasizes that, while MRI is highly valuable, intraoperative exploration remains critical in complex cases [17].

The surgical distribution in our study reflected global practices, where procedures such as Growing Rod Fixation, Posterior Vertebral Column Resection, and Instrumented Spine Fusion are tailored to deformity severity and underlying anomalies. Postoperative outcomes in our patients were favorable, which is consistent with international literature reporting improved neurological recovery after early detection and management of anomalies [18,19].

Overall, our findings reaffirm the clinical importance of routine MRI in CS patients. They support earlier recommendations for selective but proactive screening, particularly in patients with severe scoliosis, atypical curve patterns, or neurological symptoms [20,21,22].

Study Limitations and Future Directions

This study has several limitations. First, it was retrospective and relied on existing medical and imaging records, which may introduce information bias. Second, being a single-center study, the findings may not fully represent the broader Pakistani population. Third, discrepancies between MRI and intraoperative findings indicate that imaging alone may not always be sufficient for comprehensive assessment.

Future research should include multicenter prospective studies to improve generalizability and reduce bias. Incorporating genetic testing may provide further insights into the etiology of congenital scoliosis in local populations [10]. Advances in imaging, such as limited-sequence or high-resolution MRI, could also be evaluated to improve diagnostic accuracy and cost-effectiveness [13]. Long-term follow-up studies will be essential to assess the functional and neurological outcomes of patients undergoing surgical correction in the presence of intraspinal anomalies.

Conclusion

This study highlights a significant prevalence (20.5%) of intraspinal anomalies among congenital scoliosis patients, with syrinx being the most common finding. The severity of scoliosis was positively associated with anomalies such as syringomyelia and diastematomyelia, emphasizing the need for routine preoperative MRI. Although some discrepancies exist between imaging and intraoperative findings, MRI remains an indispensable tool for early detection and surgical planning. Tailored surgical interventions led to favorable outcomes in most patients, underscoring the importance of individualized management strategies. These findings support the role of routine MRI screening in improving safety and outcomes in congenital scoliosis care.

Authors' Contributions

All authors meet the ICMJE criteria for authorship. They have reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.
Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.

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