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A clinical case series

Spinal Deformity Surgery in Prepubertal Children with Complex Vertebral Malformations: A Single-Center Case Series

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Abstract

Congenital spinal deformities in prepubertal children are heterogeneous, progressive, and frequently accompanied by associated anomalies, making surgical planning challenging.

Objective: To describe the radiographic and clinical characteristics of a single-center series of surgically treated prepubertal children with complex vertebral malformations.

Case Presentation. This retrospective descriptive case series included 12 children who underwent surgery between 2019 and 2023 at a tertiary referral center. Demographic variables, deformity pattern, associated anomalies, number of surgeries and hospitalizations, and radiographic parameters were reviewed. All patients underwent posterior correction and fusion using predominantly transpedicular instrumentation; growth-friendly techniques were not used. Primary outcomes were pre- to postoperative changes in scoliosis Cobb angle and, where paired data were available, kyphosis angle.

The mean age at first surgery was 9.2 ± 1.6 years (range, 7–11). The mean scoliosis Cobb angle improved from 30.8° ± 12.1° preoperatively to 9.4° ± 8.8° at the latest postoperative follow-up, corresponding to a mean reduction of 21.3° and a 69.2% reduction based on group means. Eight of the 12 patients achieved >50% coronal correction. Kyphosis measurements were numerically available in 6 patients preoperatively and as paired postoperative values in 5; in this paired subgroup, mean kyphosis improved from 49.5° ± 30.3° to 23.0° ± 15.4°, corresponding to a mean reduction of 26.5°. Associated anomalies or syndromic conditions were documented in 6 patients (50.0%). The mean number of surgeries was 1.5 ± 0.5 per patient, and the mean number of hospitalizations was 2.2 ± 1.1. No major neurological deficits or deep infectious complications were documented in the available records.

Conclusions. In this case series, posterior surgical correction for complex congenital spinal deformities in prepubertal children provided substantial coronal correction, clinically meaningful sagittal improvement in patients with available paired measurements, and a moderate treatment burden.

Keywords: congenital spinal deformity, case series, prepubertal children, vertebral malformations, spinal surgery, scoliosis, kyphoscoliosis.

1. Introduction

Congenital spinal deformities arise from failures of vertebral formation, segmentation, or combined malformations and often become clinically relevant early in life. In contrast to adolescent idiopathic scoliosis, these deformities are usually rigid, frequently progressive, and may be associated with kyphosis, thoracic insufficiency, and anomalies of other organ systems [1–3]. In addition to coronal deformity progression, sagittal imbalance and junctional problems may substantially affect mechanical outcomes and overall clinical burden, further complicating treatment planning [4]. As a result, management requires not only deformity correction but also careful consideration of growth potential, neurological safety, sagittal profile, and associated conditions.

Surgical treatment is generally indicated for progressive deformity or for curves that have already reached magnitudes unlikely to remain stable with observation alone. In younger children, the choice between definitive fusion and growth-friendly strategies remains complex. Growth-friendly systems preserve spinal growth, but they are also associated with repeated procedures, unplanned returns to the operating room, and a higher cumulative complication burden [1,5,6]. Conversely, definitive posterior correction may reduce the number of interventions in selected patients with focal or rigid deformities, particularly when short-segment stabilization is feasible [2,7]. Recent growth-based decision-making concepts in congenital scoliosis with multiple vertebral anomalies further emphasize that surgical strategy should be individualized according to deformity morphology, progression risk, and remaining growth potential [8]. In selected rigid kyphoscoliotic deformities, posterior-based corrective procedures have also been shown to provide meaningful radiographic improvement when appropriately indicated [9].

Another important feature of congenital spinal deformity is its association with extracolumnar and intraspinal abnormalities. Prior studies have reported cardiac, genitourinary, craniofacial, and neural axis anomalies in a substantial proportion of patients, underscoring the need for multidisciplinary preoperative evaluation [3,10,11]. Against this background, reporting institutional surgical experience remains valuable, especially for centers managing complex congenital deformities in resource-constrained settings.

The aim of this study was to present a single-center retrospective case series of prepubertal children with complex vertebral malformations who underwent surgical correction, with emphasis on radiographic correction, associated anomalies, and overall treatment burden.

2. Case Presentation

This retrospective descriptive case series included 12 children who underwent surgery at the National Scientific Center of Traumatology and Orthopedics named after Academician N. Batpenov. Institutional records were reviewed to identify children aged 7–12 years with congenital spinal deformity and multiple vertebral anomalies who underwent operative treatment between 2019 and 2023. Only patients with available preoperative radiographs, latest postoperative radiographs, and sufficiently complete clinical records were included. The minimum postoperative follow-up was 2 years.

All cases represented structural congenital deformities related to vertebral malformations. The operative strategy consisted of posterior deformity correction and fusion using predominantly transpedicular instrumentation. Hooks were used selectively in the upper thoracic or cervicothoracic region when pedicle anatomy was unfavorable. Short-segment fusion was preferred whenever it was technically and biologically appropriate. Growth-friendly techniques were not used in this series.

For each patient, the following variables were extracted from the clinical and operative records: year of first surgery, age at first surgery, deformity type, associated anomalies or syndromic conditions, number of spinal operations, number of hospitalizations related to spinal treatment, and radiographic parameters.

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Coronal deformity was assessed using the scoliosis Cobb angle measured on standing radiographs before surgery and at the latest available postoperative follow-up. Sagittal deformity was assessed using the kyphosis angle when this variable was numerically recorded in the chart. For patients who underwent more than one operation, the latest available postoperative radiograph after completion of the treatment course was used for analysis.

The primary outcome was the change in scoliosis Cobb angle from the preoperative assessment to the latest postoperative follow-up. Secondary descriptive outcomes included change in kyphosis angle in patients with paired measurements, frequency of associated anomalies, number of surgeries, and number of hospitalizations. Because the series was small and clinically heterogeneous, the statistical analysis was limited to descriptive methods. Continuous variables are presented as mean ± standard deviation, and categorical variables as counts and percentages.

The study was conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki. All data were anonymized before analysis. Because of the retrospective design and the use of non-identifiable information, individual consent for study participation was not additionally required; however, consent for diagnostic and surgical procedures had been obtained from parents or legal guardians as part of routine care.

Key results

12 children met the eligibility criteria. The mean age at first surgery was 9.2 ± 1.6 years (range, 7–11). Four patients (33.3%) were classified as having scoliosis and eight (66.7%) as having kyphoscoliosis. Associated anomalies or syndromic conditions were documented in 6 patients (50.0%). These included cardiac anomalies or variants in three patients, Klippel–Feil syndrome in two, syringomyelia in one, hypermobility syndrome in one, and craniofacial anomalies in one; several patients had more than one associated condition.

All patients underwent posterior surgical correction. The mean number of spinal operations was 1.5 ± 0.5 per patient (range, 1–2); six patients required one operation and six required two procedures. The mean number of hospitalizations related to spinal treatment was 2.2±1.1 (range, 1–5). No major neurological deficits or deep infections were documented in the available records.

Radiographic correction in the coronal plane was observed in nearly all cases. The mean scoliosis Cobb angle decreased from 30.8° ± 12.1° preoperatively to 9.4° ± 8.8° at the latest postoperative follow-up, corresponding to a mean absolute reduction of 21.3°. Based on the difference between group means, this represented a 69.2% reduction in coronal deformity. Eight of the 12 patients achieved more than 50% correction. In one patient, the scoliosis angle remained unchanged at 20° preoperatively and postoperatively; however, this case was characterized by a predominantly kyphotic deformity, with kyphosis improving from 86° to 17°.

Numeric preoperative kyphosis values were available in 6 patients, whereas paired postoperative sagittal measurements were available in 5. In this paired subgroup, mean kyphosis improved from 49.5° ± 30.3° to 23.0° ± 15.4°, corresponding to a mean reduction of 26.5°. The largest sagittal corrections were observed in patients with marked preoperative deformity, including reductions from 62° to 12° and from 86° to 17°.

Table 1 - Radiographic outcomes at baseline and latest postoperative follow-up

Outcome measure	Preoperative	Postoperative	Mean improvement
Scoliosis Cobb angle (all patients, n = 12)	30.8 ± 12.1	9.4 ± 8.8	−21.3° (69.2%)
Kyphosis angle (paired subgroup, n = 5)	49.5 ± 30.3	23.0 ± 15.4	−26.5° (53.5%)

Note: Kyphosis analysis was limited to patients with paired numeric pre- and postoperative measurements

4. Discussion

This single-center retrospective case series suggests that posterior surgical correction in prepubertal children with complex congenital vertebral malformations can achieve substantial coronal correction with an acceptable overall treatment burden. The mean scoliosis Cobb angle decreased from 30.8° to 9.4°, corresponding to a 69.2% reduction based on group means, and eight of the 12 patients achieved more than 50% correction. Although direct comparison across studies remains difficult because congenital deformities are morphologically heterogeneous and surgical indications vary, the present findings are consistent with the broader concept that timely and individualized operative management may prevent progression and provide meaningful deformity control in selected patients with congenital scoliosis [2,6,9].

Sagittal correction was also clinically relevant in the subgroup with available paired measurements. In these patients, mean kyphosis improved from 49.5° to 23.0°, corresponding to a mean reduction of 26.5°.

Importantly, in one patient the scoliosis angle remained unchanged at 20° preoperatively and postoperatively; however, this case was characterized by a predominantly kyphotic deformity, with kyphosis improving from 86° to 17°. This observation indicates that coronal correction alone may underestimate the overall surgical benefit in selected patients with combined deformities. Restoration of sagittal alignment is clinically important because persistent kyphotic deformity and junctional malalignment may adversely affect mechanical outcomes and increase the burden of spinal deformity surgery [4]. Similar meaningful radiographic improvement after posterior-based corrective procedures has been reported in pediatric patients with severe rigid kyphoscoliosis [9]. In addition, although our cohort was not focused specifically on cervical deformity, the broader pediatric literature also highlights the importance of carefully addressing kyphotic alignment in the cervicothoracic region when present [12]. At the same time, sagittal radiographic data were incomplete in part of the present cohort, and the small number of paired cases precludes firm conclusions regarding sagittal outcomes across the entire series.

An important practical observation in this study is the moderate treatment burden. All patients were managed without growth-friendly techniques, and no child underwent more than two procedures. This contrasts with the repeated lengthening strategy often required in growth-friendly constructs, which has been associated with higher rates of complications, reoperations, and unplanned returns to the operating room in pediatric spinal deformity surgery [1,6]. From a health-service perspective, treatment burden is also relevant because pediatric deformity surgery may be associated with prolonged hospitalization, readmission, and additional resource utilization [5]. Nevertheless, such comparisons should be interpreted cautiously, because our cohort consisted of selected prepubertal patients with congenital vertebral malformations who were managed using a different clinical rationale and age-specific strategy. In this context, our findings are in line with recent growth-based decision-making concepts emphasizing that surgical strategy in congenital scoliosis with multiple vertebral anomalies should be individualized according to deformity pattern, progression risk, and remaining growth potential [8].

Half of the patients in this series had associated anomalies or syndromic conditions, including cardiac findings, Klippel–Feil syndrome, syringomyelia, hypermobility syndrome, and craniofacial abnormalities. This observation is consistent with previous reports showing that congenital scoliosis is frequently accompanied by extracolumnar and intraspinal anomalies [3,10,11]. Accordingly, our findings support the need for comprehensive multidisciplinary preoperative assessment, including evaluation for neural axis and systemic abnormalities that may influence timing of surgery, perioperative safety, and overall treatment planning.

The present study has several limitations. First, it is a retrospective case series from a single institution with a small sample size, which limits generalizability. Second, the cohort was clinically heterogeneous with respect to deformity morphology and associated anomalies. Third, sagittal radiographic data were incomplete, so kyphosis analysis could only be performed in a subset of patients. Fourth, the study did not include standardized functional or health-related quality-of-life outcomes. Fifth, despite a minimum postoperative follow-up of 2 years, the absence of a comparison group precludes any inference regarding superiority of one surgical strategy over another. Despite these limitations, the study provides a realistic description of institutional experience in managing complex congenital deformities during the prepubertal period and may be useful for contextualizing surgical decision-making in similar clinical settings.

5. Conclusions

In this retrospective single-center case series, surgical correction of complex congenital spinal deformities in prepubertal children achieved substantial coronal improvement and clinically meaningful sagittal correction in patients with available paired measurements. The treatment burden remained moderate, with one or two procedures per patient, and no major neurological deficits or deep infections were documented in the available records. These findings support carefully selected posterior correction and fusion as a reasonable treatment option for prepubertal patients with complex vertebral malformations, while also underscoring the importance of multidisciplinary evaluation and cautious interpretation of results in small, clinically heterogeneous series.

Conflict of interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Препубертаттық жастағы күрделі омыртқа аномалиялары бар балалардағы омыртқа деформациясының хирургиялық түзету: Бір орталықтың клиникалық жағдайлар сериясы

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Түйіндеме

Препубертаттық жастағы балалардағы омыртқаның туа біткен деформациялары құрылымдық әртектілігімен, үдемелі ағымымен және қатар жүретін аномалиялардың жиі кездесуімен сипатталады, бұл хирургиялық емдеуді жоспарлауды күрделендіреді.

Зерттеудің мақсаты: хирургиялық ем алған күрделі омыртқа аномалиялары бар препубертаттық жастағы балалардың бір орталықтағы сериясында радиологиялық және клиникалық сипаттамаларды талдау.

Клиникалық жағдайларды сипаттау. Зерттеу 2019–2023 жылдар аралығында мамандандырылған орталықта ота жасалған 12 баланы қамтыған ретроспективті сипаттамалық клиникалық жағдайлар сериясы негізінде жүргізілді. Демографиялық көрсеткіштер, деформация түрі, қатар жүретін аномалиялар, оталар мен госпитализациялар саны, сондай-ақ радиологиялық параметрлер талданды. Барлық науқастарға транспедикулярлы фиксацияны қолдана отырып артқы қолжетімділік арқылы түзету және спондилодез орындалды; growth-friendly технологиялары қолданылған жоқ. Негізгі нәтижелік көрсеткіштер ретінде сколиоз кезіндегі Cobb бұрышының ота дейінгі және отадан кейінгі өзгерістері, ал жұпталған деректер болған жағдайда кифоз бұрышының динамикасы бағаланды.

Алғашқы ота жасалған кездегі орташа жас 9,2 ± 1,6 жасты құрады (7–11 жас). Сколиоз кезіндегі Cobb бұрышының орташа мәні операцияға дейін 30,8° ± 12,1°-тан отадан кейінгі соңғы бақылауда 9,4° ± 8,8°-қа дейін төмендеді, бұл орташа 21,3°-қа азаюға және короналдық деформацияның 69,2%-ға түзетілуіне сәйкес келді. 12 науқастың 8-інде короналдық түзету 50%-дан асты. Кифоз көрсеткіштері отаға дейін 6 науқаста, ал отадан кейінгі жұпталған сагитталды өлшемдер 5 науқаста қолжетімді болды; осы топта кифоздың орташа мәні 49,5° ± 30,3°-тан 23,0° ± 15,4°-қа дейін төмендеп, орташа 26,5°-қа азайды. Қатар жүретін аномалиялар немесе синдромдық жағдайлар 6 науқаста (50,0%) анықталды. Бір науқаста шаққандағы оталардың орташа саны 1,5 ± 0,5, ал госпитализациялардың орташа саны 2,2 ± 1,1 болды. Қолжетімді медициналық құжаттарда ауыр неврологиялық немесе терең инфекциялық асқынулар тіркелмеген.

Қорытынды. Осы клиникалық жағдайлар сериясында препубертаттық жастағы омыртқаның туа біткен ақауларымен жүретін деформациялары бар балаларға артқы түзету және спондилодез жүргізу деформацияның айқын түзетілуін және емдеу жүктемесінің орташа деңгейде болғанын көрсетті.

Түйін сөздер: омыртқаның туа біткен деформациясы, клиникалық жағдайлар сериясы, препубертаттық жастағы балалар, омыртқа аномалиялары, омыртқа хирургиясы, сколиоз, кифосколиоз.

Хирургическое лечение деформаций позвоночника у детей препубертатного возраста со множественными аномалиями позвонков: Серия клинических случаев одного центра

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Резюме

Врожденные деформации позвоночника у детей препубертатного возраста характеризуются гетерогенностью, прогрессирующим течением и частым сочетанием с сопутствующими аномалиями, что затрудняет планирование хирургического лечения.

Цель исследования: описать рентгенологические и клинические характеристики одноцентровой серии детей препубертатного возраста со сложными аномалиями позвонков, которым было выполнено хирургическое лечение.

Презентация клинических случаев. В ретроспективную описательную серию клинических случаев включены 12 детей, перенесших операцию в период с 2019 по 2023 год в специализированном центре третьего уровня. Проанализированы демографические показатели, тип деформации, сопутствующие аномалии, число операций и госпитализаций, а также рентгенологические параметры. Всем пациентам выполнены коррекция деформации и спондилодез из заднего доступа с преимущественным применением транспедикулярной фиксации; growth-friendly технологии не использовались. Основными исходами были изменения угла Cobb при сколиозе до и после операции, а при наличии парных данных – изменения угла кифоза.

Средний возраст на момент первой операции составил 9,2 ± 1,6 года (диапазон 7–11 лет). Среднее значение угла Cobb при сколиозе уменьшилось с 30,8° ± 12,1° до операции до 9,4° ± 8,8° при последнем послеоперационном наблюдении, что соответствовало среднему снижению на 21,3° и уменьшению корональной деформации на 69,2% по групповым средним значениям. У 8 из 12 пациентов достигнута коррекция корональной деформации более чем на 50%. Значения кифоза были доступны до операции у 6 пациентов, а парные послеоперационные данные – у 5; в этой подгруппе средний угол кифоза уменьшился с 49,5° ± 30,3° до 23,0° ± 15,4°, что соответствовало среднему снижению на 26,5°. Сопутствующие аномалии или синдромальные состояния были зарегистрированы у 6 пациентов (50,0%). Среднее число операций на одного пациента составило 1,5 ± 0,5, а среднее число госпитализаций – 2,2 ± 1,1. Тяжелых неврологических нарушений или глубоких инфекционных осложнений не отмечено.

Выводы. В данной серии клинических случаев хирургическая коррекция врожденных деформаций позвоночника у детей препубертатного возраста из заднего доступа обеспечила значимую коррекцию деформации и умеренную лечебную нагрузку.

Ключевые слова: врожденная деформация позвоночника, серия клинических случаев, дети препубертатного возраста, аномалии позвонков, хирургия позвоночника, сколиоз, кифосколиоз.

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