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Mid-term clinical outcomes of posterior spinal instrumentation surgery in thoracolumbar and lumbar curvatures of adolescent idiopathic scoliosis patients

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Abstract

Background: The aim of this study is to evaluate the mid-term surgical, clinical, and radiological outcomes of posterior spinal instrumentation (PSI) in patients diagnosed with adolescent idiopathic scoliosis (AIS) presenting thoracolumbar and lumbar curvatures. **Methods:** This retrospective study included 43 AIS patients who underwent posterior spinal fusion between 2020 and 2022 at two different centers. Patients with syndromic scoliosis or incomplete data were excluded. All procedures were performed by the same surgical team using a posterior approach under general anesthesia. A minimum of 10 and a maximum of 15 levels were instrumented from T2 to S1. In addition to standard instrumentation, vertebral column resection (VCR), pedicle subtraction osteotomy (PSO), and ponte osteotomies were applied in selected cases. Demographic data, operative parameters (duration, blood loss, transfusion), hospital stay, radiological outcomes (Cobb angle, T1 tilt, lowest instrumented vertebra [LIV] angle), pulmonary function test results (FVC, FEV1), and scoliosis research society 24-item questionnaire (SRS-24) were collected and analyzed. **Results:** The mean age of the patients was 14.83 ± 2.12 years, and the average follow-up period was 15 ± 7.74 months. The mean preoperative Cobb angle was 48.93°, which improved to 2.88° postoperatively. Postoperative improvements were also observed in T1 tilt and LIV angles. Pulmonary function tests revealed increased FVC and FEV1 values after surgery. The mean SRS-24 score was 96 ± 19, reflecting high patient satisfaction and functional recovery. Postoperative complications included cerebrospinal fluid leakage in three patients (treated successfully with epidural blood patch), pleural injury in one patient (repaired intraoperatively), and two cases of surgical site infection (managed with antibiotics, debridement, and hyperbaric oxygen therapy). No major neurological complications were recorded. **Conclusions:** Posterior spinal instrumentation is an effective and safe surgical technique for correcting spinal deformity and improving respiratory function in AIS patients with thoracolumbar and lumbar curves. The low complication rates and high SRS-24 scores observed in this study align with existing literature and highlight the reliability of PSI when performed with proper indication and planning. Early diagnosis and timely surgical intervention are crucial for achieving optimal outcomes in this patient population.

Keywords: Adolescent idiopathic scoliosis, posterior spinal instrumentation, thoracolumbar curve, lumbar curve, SRS-24, Cobb angle

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Introduction

A disturbance in the alignment of the spine in all three planes is defined as spinal deformity. The prevalence of scoliosis in the general population ranges from 0.9-12% [1-3]. While congenital, neuromuscular, hereditary, and degenerative causes are among its etiologies, adolescent idiopathic scoliosis (AIS) is the most common deformity with unknown etiology [1-3]. Idiopathic scoliosis is divided into infantile, juvenile, adolescent, and adult subtypes; it is most observed in individuals aged 10–18 years [1]. In advanced curves, in addition to cosmetic concerns, social and psychological problems may arise [2]. Curvatures exceeding 100–110˚ can lead to cardiopulmonary complications [3].

In diagnosis, age, family history, skeletal maturity, and menarche are important; physical examination typically reveals shoulder and trunk asymmetry and the presence of a “rib hump.” In atypical findings or rapid progression, spinal magnetic resonance imaging (MRI) is recommended [4]. The impact of AIS on quality of life is evaluated through scoliosis research society 24-item questionnaire (SRS-24) [5,6].

In 90% of cases, a right thoracic or left lumbar curve is observed [4]. Underlying pathology should be investigated in atypical curves. Accurate treatment requires classification systems. The first such system was developed by Ponseti and Friedman [7]. The King-Moe classification introduced the concept of structural curves into the literature [8,9]. The Lenke classification guides surgical planning by assessing deformities in the coronal and sagittal planes [10,11]. Classification is based on the apical vertebra, and bending and traction radiographs are important [12,13]. Structural curves are those with a Cobb angle > 25˚ and that do not fall below 25˚ on bending radiographs. Lumbar and thoracic modifiers play a role in fusion planning [14,15].

Qiu et al. developed the Peking Union Medical College (PUMC) classification, which includes 13 subtypes [16]. Its use in conjunction with the Lenke classification offers a more comprehensive evaluation [15]. In this study, surgical planning was primarily based on the Lenke classification to determine structural curves and select fusion levels. In cases where curve classification was ambiguous or three-dimensional complexity was high, the PUMC system was also utilized to support the surgical strategy.

The Risser staging assesses skeletal maturity based on iliac apophysis ossification [17]. Reem et al. reported this system to be reliable in evaluating growth potential [18]. While 10% of scoliosis patients require treatment, only 0.1% need surgery [19]. The goal of surgery is to halt the progression of the curvature, achieve correction, improve trunk balance, and reduce complications [20]. Curvatures exceeding 40˚ may continue to progress in adulthood [21]. Surgery is recommended for curves < 45° in patients with Risser stage 2 or below, and for curves > 50° in those with Risser stage 3 or above [22,23]. Surgical indication includes thoracic curves ≥ 50° and lumbar curves > 40–45° [24].

In the evaluation of surgical outcomes in AIS, follow-up durations of 24 months or longer are commonly defined as “mid-term” in the literature. However, several studies have also referred to 12–24-month follow-up periods as “mid- term.” Therefore, the 15-month mean follow-up duration in our study may be considered within the scope of mid-term evaluation [25].

One of the most widely used approaches in AIS treatment is posterior spinal instrumentation (PSI). This technique provides sagittal plane control and pulmonary protection. It also offers good correction in the coronal plane by addressing vertebral rotation. However, it involves risks such as muscle injury, infection, and larger fusion areas (Figure 1).

The aim of this retrospective, single-center study is to evaluate the surgical, clinical, and radiological outcomes of PSI performed by the same surgical team in patients with thoracolumbar/lumbar AIS.

Materials and methods

This study was planned using the data of 53 patients who underwent surgery between 2020 and 2022 at Kayseri Training and Research Hospital and Kayseri City Training and Research Hospital. Ten patients were excluded from the study due to the presence of various syndromes, and the remaining 43 patients were included.

All surgeries were performed by the same experienced orthopedic spine surgeon. All operations were performed under general anesthesia, in the prone position, and using a posterior approach. The level of instrumentation extended from T2 superiorly to S1 inferiorly, with posterior spinal fusion applied to a minimum of 10 and a maximum of 15 segments. Additionally, one patient underwent VCR osteotomy, one patient had a PSO, and 18 patients had ponte osteotomies. The surgical planning process was based primarily on the Lenke classification, which guided the identification of structural curves and determination of fusion levels. When curve flexibility or structurality was unclear, the PUMC classification was employed in addition to Lenke to provide a more refined fusion strategy. Posterior instrumentation was preferred for patients with Lenke type 1–6 curves with structural thoracolumbar or lumbar components. Ponte osteotomies were preferred in patients with moderate curve rigidity and to enhance sagittal plane correction without extensive destabilization. PSO was performed in cases with severe sagittal imbalance and stiff thoracolumbar transitions. VCR was reserved for patients with complex, rigid, three-dimensional deformities that could not be adequately corrected using conventional posterior instrumentation alone.

Demographic characteristics, clinical data (amount of bleeding, transfusion volume, operation time, duration of stay in the ward and intensive care unit, perioperative and postoperative complications), radiological parameters (Cobb angle, apical vertebra translation, T1 tilt, and lowest instrumented vertebra [LIV] angles), pulmonary function tests, and SRS-24 scores (pain, self-image, function, activity level, postoperative self-image, postoperative function, and patient satisfaction) were recorded.

Patients without preoperative and postoperative X-ray images during follow-up, those with incomplete SRS-24 data, or those who did not meet the AIS criteria were excluded from the study.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA), which was the latest available version in 2022. Descriptive statistics were presented as mean ± standard deviation (SD) for continuous variables and as frequency (n) and percentage (%) for categorical variables. The paired samples t-test was used to compare preoperative and postoperative data. A p-value ¡0.05 was considered statistically significant.

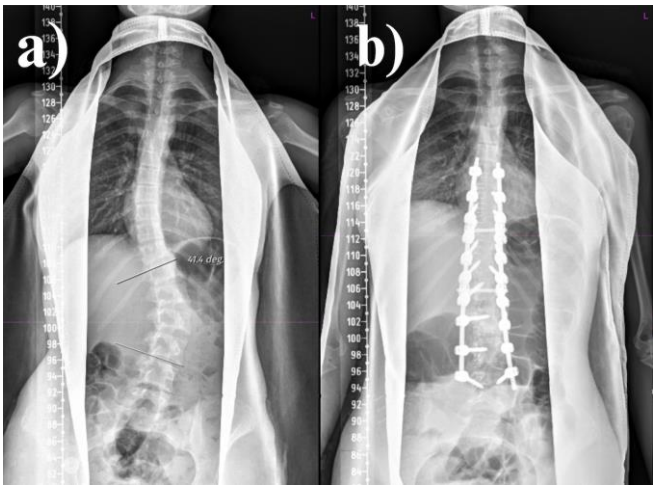

Fig. 1: a) Preoperative scoliosis radiograph of a 14-year-old female patient, b) Radiographic appearance of the patient after posterior spinal instrumentation surgery.

Results

Of the 43 patients included in the study, 30 were female and 13 were male. The mean age was 14.83 ± 2.12 years, and the median age was 15 years (range: 9–18 years). The mean follow-up period was 15 ± 7.74 months. Risser stage 5 was observed in 44.2The average operation time was 3.87 ± 0.87 hours (range: 2–6 hours). The mean postoperative hemovac drainage volume was 745.34 ± 329.64 mL, and the mean transfusion volume during and after surgery was 1.81 ± 1.78 units. The average hospital stay was 6.47 ± 2.71 days, ranging from 4 to 20 days. One patient was monitored in the intensive care unit for five days, while two patients were followed for two days each before being transferred to the ward. Radiologically, the mean preoperative Cobb angle was 48.93 ± 9.57˚, which decreased to 2.88 ± 5.31˚ postoperatively. The preoperative T1 tilt was 4.54 ± 7.21˚, decreasing to 3.28 ± 5.08˚ postoperatively. The LIV angle decreased from 12.74 ± 5.97˚ preoperatively to 2.58 ± 3.97˚ postoperatively.

In pulmonary function tests, FVC increased from 3.19 ± 1.22 L to 3.59 ± 1.62 L, and FEV1 increased from 2.66 ± 0.98 L/sec to 2.96 ± 1.28 L/sec postoperatively. Both improvements were statistically significant (p ¡ 0.05).

The mean SRS-24 score was 96 ± 19, reflecting high patient satisfaction and functional recovery. Due to limitations in retrospective data collection, subdomain scores of the SRS-24 could not be extracted individually. Postoperative cerebrospinal fluid (CSF) leakage that did not resolve spontaneously occurred in three patients, all of whom were successfully treated with epidural blood patch [26]. One patient had an intraoperative pleural injury, which was repaired. In addition, two patients developed postoperative infections, which were successfully treated with surgical debridement and hyperbaric oxygen therapy along with antibiotic treatment.

Discussion

Adolescent idiopathic scoliosis (AIS) is one of the most common spinal deformities seen in individuals aged 10–18 years and has an etiology that remains unclear [1]. With a prevalence ranging from 0.9-12%, it poses a significant public health concern, often progressing silently during growth and causing not only cosmetic issues but also serious psychosocial and physiological complications [2,3]. Although only 0.1% of patients require surgical intervention, properly indicated surgeries can lead to dramatic improvements in quality of life [19,20].

In this study, we evaluated the clinical, surgical, and radiological outcomes of patients diagnosed with AIS who underwent posterior spinal instrumentation. The mean preoperative Cobb angle was 48.93˚, which decreased to 2.88˚ postoperatively, indicating the effectiveness of PSI in correcting deformities in the coronal plane. This high correction rate was achieved through surgical planning based on the Lenke classification [10], which guides decisions by considering deformities in both the coronal and sagittal planes and evaluating curve structurality [11–13]. Niemeyer et al. also reported similar correction rates, demonstrating surgical success [14].

The impact of surgery on function and quality of life was also assessed in this study. The mean SRS-24 score was 96 ± 19, indicating significant improvements in function, self-image, and patient satisfaction. These findings are supported by the multicenter study of Haher et al. [5] and long-term follow-up results from Helenius et al. [6]. Although the total SRS-24 score was available and showed favorable results, the absence of subdomain-level data due to incomplete documentation limited our ability to assess specific areas of functional and psychosocial recovery. Future prospective studies are recommended to include complete subdomain analysis for more detailed evaluation.

Despite the invasive nature of the procedure, the complication rate was low in this study. CSF leakage in three patients was successfully treated with epidural blood patch, a pleural injury in one patient was repaired intraoperatively, and two postoperative infections were managed with debridement and hyperbaric oxygen therapy. These results align with the low complication rates reported by El-Hawary and Chukwunyerenwa [23].

The mean operation time was 3.87 ± 0.87 hours, with a mean hemovac drainage of 745 mL and a transfusion requirement of 1.81 units. These findings are consistent with those of Tambe et al. (operation duration) and Weinstein et al. (blood loss) [3,20]. Furthermore, improvements in FVC and FEV1 indicate a positive impact on respiratory function, which can be attributed to preservation of the thoracic cage and correction of vertebral rotation. The increase in these pulmonary parameters was statistically significant ($p < 0.05$), supporting the clinical relevance of the observed improvement. Maruyama and Takeshita also reported that scoliosis surgery improves pulmonary function [27]. Regarding surgical indications, the majority of patients in our study were selected in accordance with criteria defined in the current literature. Curves > 45˚ in patients with Risser stage ≤ 2 and curves > 50˚ in those with Risser stage ≥ 3 are considered surgical indications [22,23]. In addition, curves > 40˚ are known to progress into adulthood, making surgery necessary in such cases [21].

Classification systems are of great importance in surgical planning. The PUMC system, when used alongside the Lenke classification, provides a more comprehensive evaluation and

supports the surgeon's decision-making process [15,16]. Similarly, the Risser classification is an essential tool for assessing growth potential [17,18].

This study has several limitations. First, the retrospective design may introduce bias in data collection and limits the ability to draw causal inferences. Second, the lack of a control or comparison group restricts the interpretation of outcomes relative to other treatment modalities. Regarding follow-up, although the mean follow-up duration was 15 months—which aligns with some reports in the literature that define 12–24 months as mid- term follow-up—it should be noted that other sources define mid-term as 24 months or longer. Nonetheless, recent studies have increasingly accepted follow-up periods between 12 and 24 months as mid-term, particularly in adolescent idiopathic scoliosis surgery outcomes [25]. Therefore, the 15-month average follow-up in our study can be reasonably categorized as mid-term. However, for comprehensive evaluation of long-term surgical efficacy, extended follow-up remains essential. Additionally, the relatively small sample size (n=43) limits statistical power and precludes robust subgroup analysis. While the total SRS-24 score was available, subdomain-level data could not be retrieved due to incomplete documentation. Moreover, sagittal alignment parameters such as thoracic kyphosis and lumbar lordosis were not routinely recorded, limiting the assessment of three-dimensional correction. Although fusion levels were individualized based on curve characteristics, detailed vertebral level documentation was not consistently available. Future prospective studies are planned with larger cohorts, longer follow-up durations, and comprehensive evaluation of sagittal/coronal alignment and patient-reported outcomes, including SRS-24 subdomains.

Conclusions

Adolescent idiopathic scoliosis is one of the most common childhood deformities and, if left untreated, can lead to significant morbidity. Corrective surgery using posterior spinal instrumentation not only improves deformity correction but also enhances respiratory function, has a low complication rate, and yields high patient satisfaction. Early diagnosis and well-timed surgical planning are key factors that enhance treatment success.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by SB, EB and MAD. The first draft of the manuscript was written by SB, EB and MAD and all authors commented on previous versions of the manuscript. All authors read and approved of the final manuscript.

Statements and declarations

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Conflict of Interest

The authors declare that they have no conflict of interest. This study was presented as a paper at the 35th Scientific Congress of the Turkish Neurosurgical Society in 2022.

Ethical statement

The University of Health Sciences Kayseri City Training and Research Hospital Education Planning Board approved the study protocol (Approval No: 20.03.2025/76397871). The authors confirm that this retrospective study was conducted in accordance with the ethical standards of the Declaration of Helsinki and its later amendments.

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