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# Pedicle subtraction osteotomy in patient with congenital kyphosis

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## Abstract

**Introduction** A disorder causes congenital kyphosis in the last stages of ossification and cartilage formation during embryonic development. The main treatment for this disease is surgery with various methods. The present study was performed to evaluate the results of the posterior surgery.

**Methods** This study was a descriptive study comparing the results before and after surgery which was performed in 2022 on 14 patients with the congenital kyphosis referred to Al-Zahra Hospital in Isfahan. Initial assessments were performed, and the patient underwent surgery. The patients were re-evaluated immediately after surgery which were followed up and evaluated two years after surgery. Data were collected by a checklist and described and analyzed in SPSS software version 22.

**Results** The mean age of the patients was 23.15 ± 13.24 years, 7 patients (50%) were male, and the mean duration of surgery was 405.85 ± 123.99 min. Seven patients (50%) were under 18 years old. No disease died and the highest T12 involvement was in 5 patients (35.8%). Sagittal Vertical Axis, Kyphosis Angle and Lumbar Lordosis decreased in two stages immediately after surgery and follow-up, which were statistically significant ($P < 0.05$). No associated neurologic abnormalities was found during a physical examination or magnetic resonance imaging. In three phases (before, immediately after surgery, and follow-up), the mean of the Sagittal Vertical Axis, and Lumbar Lordosis in adults (over 18 years) and children (under 18 years) was not substantially different ($P > 0.05$). The mean Kyphosis Angle were significantly different in adults, and children at follow-up stages ($P < 0.05$). Because one of the children had a device filler in the follow-up stage.

**Conclusions** PSO can be used as a safe and effective technique to treat and correct Sagittal Vertical Axis, Kyphosis angle, Lumbar lordosis.

**Keywords** Pedicle subtraction osteotomy, Congenital kyphosis, Lumbar lordosis, Sagittal vertical axis

## Introduction

Congenital spinal deformities are complex syndromes usually associated with deformities in other body parts [1]. One of these deformities is the congenital kyphosis or kyphoscoliosis caused by a developmental vertebral deformity which disrupts the anterior or anterior longitudinal growth of the transverse axis of the rotation of the vertebrae in the sagittal plane [2].

Congenital kyphosis is a sagittal plane deformity that results from vertebral anomalies including failures of formation and segmentation. Congenital kyphosis often results in neurological deficits if left untreated [3], this disorder can progress to paraplegia and cardio-pulmonary dysfunction [4]. Therefore, surgery is the primary

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treatment to prevent the progression of congenital kyphosis [5].

Appropriate surgical procedure affects the success rate of operation which is selected due to the patient's age, the type of vertebral deformity, the deformity size, and the presence or absence of spinal cord compression [6].

Depending on the amount of correction required to restore sagittal balance, three methods are used: Smith-Peterson osteotomy (SPO), pedicle subtraction osteotomy, and vertebral column resection [7].

Numerous studies have emphasized the safety of the pedicle subtraction osteotomy (PSO) and reduced the risk of vascular injury and mortality in patients [8], and few studies have evaluated the postoperative complications [9].

Considering even after skeletal maturity, the congenital spinal deformity can occur continuously. In addition to the aesthetic problems, many patients have significant low back pain and functional disability in terms of the spinal imbalance associated with kyphosis or kyphoscoliosis [10]; therefore, the present study surveyed the results of PSO in patients with the congenital kyphosis.

## Methods

It was a descriptive study which compared pre- and postoperative results on the patients with congenital kyphosis referred to Al-Zahra Hospital of Isfahan in 2022. When the research project was approved by the Ethics Committee of Isfahan University of Medical Sciences, the researcher referred to Al-Zahra Hospital under the number IR.MUI.MED.REC.1397.230 and identified the patients. Patients included the congenital kyphosis patients who underwent PSO during 2018 and 2022.

Census sampling was used, and finally, 14 people were included in the present study. Inclusion criteria included all patients with congenital kyphosis who underwent PSO and expressed their consent to participate in the study. Exclusion criteria included the patients who did not refer for follow-up.

A checklist was used to gather data. To do this, the patients were first given the relevant details regarding the research's aims, and if they or their legal guardians desired to participate in the study, an informed permission form was obtained from them. Initial evaluations were carried out, and the patient was operated on. Patients were re-evaluated immediately after surgery which were followed up and evaluated two years after surgery.

All patients were contacted after two years and were asked to refer to Al-Zahra Hospital for follow-up treatment if they consented to participate in the study. They were also assured that all information would remain confidential and that no additional charges would be imposed on them.

Evaluation criteria included neurological examination, cardiac examination, and echocardiography (due to the higher prevalence of heart disease in congenital kyphosis), local radiography, Local Kyphosis, Sagittal Vertical Axis, and Lumbar Lordosis.

The rod fracture in terms of the pseudo-arthrosis, implant failure with loosening of screws, and proximal junctional kyphosis, were immediately examined and two years after surgery.

Local and lumbar lordosis were calculated before and after surgery, and their angles were calculated using lateral standing X-ray by Cobb method.

The Cobb angle, named after the American orthopedic surgeon John Robert Cobb (1903–1967), was originally used to measure coronal plane deformity on anterior-posterior plane radiographs in the classification of scoliosis.

It has subsequently been adapted to classify sagittal plane deformity, especially in the setting of traumatic thoracolumbar spine fractures.

In the setting of spine trauma and assessing sagittal plane deformity, the Cobb angle is defined as the angle formed between a line drawn parallel to the superior endplate of one vertebra above the fracture and a line drawn parallel to the inferior endplate of the vertebra one level below the fracture.

The Cobb angle is the preferred method of measuring post-traumatic kyphosis in a recent meta-analysis of traumatic spine fracture classifications [11] (Fig. 1).

To evaluate the Sagittal Vertical Axis, lateral standing X-ray was used by "drawing a straight line from the

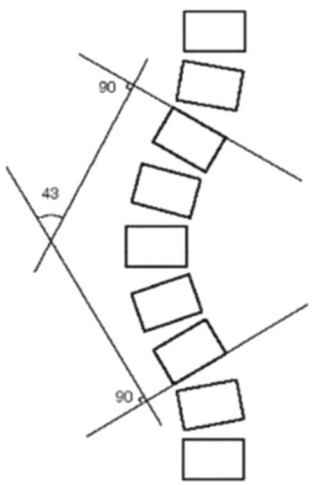


**Fig. 1** Cobb angle

C7center to the upper posterior corner of the body of the S1 vertebral body".

Two neurosurgeons performed all radiological measurements twice based on a valid and common reference. All radiographs were evaluated and compared three times.

The collected data were analyzed using SPSS ver. 22 and $P$ value < 0.05 was considered as the significance level. Mean and standard deviation were used to describe the quantitative variables, and frequency distribution and percentage were used to describe qualitative variables.

## Results

A Table 1 shows the demographic and disease characteristics of patients with congenital kyphosis.

The mean ± SD of patients' age was 23.15 ± 13.24 years, seven patients (50%) were male, and the mean duration of surgery was 405.85 ± 123.99 min.

Seven patients (50%) were under 18 years old. The mean length of ICU stay was 2 ± 0.87 days, and the mean length of hospital stay was 3.92 ± 0.82 days (Table 1). No patient died, and T12 was the highest level of involvement ($n = 5$ patients, 35.8%).

The volume of blood lost and injection was 37.42 ± 95.42 ml and 267.85 ± 89.62 ml, respectively.

A Table 2 shows patient assessments before surgery, immediately after, and after two years of follow-up.

As presented in Table 2, Lumbar Lordosis, Sagittal Vertical Axis, and Kyphosis Angle decreased at two stages immediately after surgery and follow-up, and they were statistically significant ($P < 0.05$).

A Table 3 evaluates the patients in terms of the complications.

Physical examination and magnetic resonance imaging revealed no associated neurologic abnormality.

Before the surgery, one person had sphincter disorder which did not improved after surgery and one had myelopathy which improved after two years of follow-up. Two patients had CSF leak and wound infection immediately after surgery which improved after two years of follow-up. Device filler was seen in one person after two years.

Table 4 examines the mean Sagittal Vertical Axis, Kyphosis Angle, and Lumbar Lordosis in children and adults.

According to Table 4, the mean Sagittal Vertical Axis and Lumbar Lordosis were not significantly different in adults (over 18 years), and children (under 18 years) at three stages (before, immediately after surgery, and follow-up) ($P > 0.05$). The mean Kyphosis Angle were significantly different in adults (over 18 years), and children (under 18 years) at follow-up stages ($P < 0.05$).

**Table 1** The demographic and disease characteristics of patients

| Variable | *n* (%) | Median (range) | Mean ± SD |
|---|---|---|---|
| Sex | | | |
| Male | 7 (50) | – | – |
| Female | 7 (50) | – | – |
| Age at surgery (y) | – | 18 (9–48) | 23.15 ± 13.24 |
| BMI (kg/m$^2$) | – | – | 26.1 ± 3.3 |
| Duration of surgery (min) | – | 393 (203–624) | 405.85 ± 123.99 |
| ICU stay (d) | – | 2 (1–4) | 2 ± 0.87 |
| Hospital stay (d) | – | 4 (3–5) | 3.92 ± 0.82 |
| Perioperative deaths | 0 | – | – |
| Estimated blood loss (ml) | – | 385 (230–570) | 371.42 ± 95.42 |
| Blood injection (ml) | – | 255 (0–500) | 267.85 ± 89.62 |
| Level of involvement | | | |
| L1 | 4 (28.5) | – | – |
| T6 | 2 (14.3) | – | – |
| T8 | 3 (21.4) | – | – |
| T12 | 5 (35.8) | – | – |

*y* year, *kg* Kilogram, *m* Meter, *min* minutes, *d* Day, *ml* milliliter, *SD* standard deviation

**Table 3** Patients' complications

| Variable N (%) | Preoperative | Postoperative | Follow up |
|---|---|---|---|
| Sphincter disorder | 1 | 1 | 0 |
| Myelopathy | 1 | 1 | 0 |
| CSF leak | 0 | 1 | 0 |
| Wound infection | 0 | 1 | 0 |
| Device filler | 0 | 0 | 1 |

*N* Number, *CSF* Cerebrospinal fluid

**Table 2** Patient assessments before surgery, immediately after, and after two years of follow-up

| Variable | Preoperative | Postoperative | Follow-up | P value |
|---|---|---|---|---|
| Sagittal vertical axis | 4.21 ± 3.11 | 4.14 ± 2.16 | 4.10 ± 1.06 | 0.026 |
| Kyphosis angle (mean ± SD) | 73.57 ± 12.31 | 5.71 ± 5.83 | 8.21 ± 10.67 | 0.0001 |
| Lumbar lordosis (mean ± SD) | 59.14 ± 9.50 | 46.35 ± 6.30 | 48.07 ± 6.94 | 0.001 |

*SD* standard deviation

**Table 4** Clinical characteristics of children and adults

| Variable | Age | Preoperative | Postoperative | Follow-up |
|---|---|---|---|---|
| Sagittal vertical axis | < 18 | 5.28 ± 2.21 | 4.10 ± 2 | 5.28 ± 2.08 |
| | > 18 | 3.14 ± 3.67 | 3.05 ± 1.78 | 3 ± 1.30 |
| | *P* value | 0.211 | 0.326 | 0.140 |
| Kyphosis angle (mean ± SD) | < 18 | 79.28 ± 6.07 | 6.05 ± 4.43 | 10.71 ± 6.30 |
| | > 18 | 67.85 ± 12.19 | 5.71 ± 6.07 | 5.71 ± 6.07 |
| | *P* value | 0.081 | 0.362 | 0.025 |
| Lumbar lordosis (mean ± SD) | < 18 | 59.85 ± 5.92 | 48 ± 7.02 | 46.85 ± 8.51 |
| | > 18 | 58.42 ± 12.62 | 44.71 ± 5.52 | 49.29 ± 5.34 |
| *P* value | | 0.791 | 0.350 | 0.535 |

Because one of the children had a device filler in the follow-up stage.

## Discussion

The most frequent cause of paraplegia resulting from spinal deformity in the US is congenital kyphosis, which is less frequent than congenital scoliosis [12]. Surgery may be used as the main therapy for congenital kyphosis as bracing is ineffective for these patients. In the surgical treatment of congenital kyphosis, the isolated posterior fusion of spine is usually successful for the kyphosis of less than 50–55°. In the deformities above 55 degrees, it is often argued that the combined anterior–posterior approach is more effective and produces more consistent outcomes [13].

Patients should be evaluated for intrathecal anomalies because 20–40% of congenital spinal deformity are associated with these anomalies, and since the main goal of surgery is to prevent the progression and potential neurological complications caused by spinal cord compression, it is important to pay attention to potential neurologic abnormality before corrective surgery [14]. The difference in curvature and the affected area of spine is a part of preoperative assessment to determine the most appropriate surgical technique. PSO is a modified technique which is popular among surgeons [15].

In a 6-year study on 32 patients in China, Zeng and Chen [16] found the mean preoperative kyphosis angle was 74.3° which decreased to 20° after PSO. The majority of patients with preoperative neurological symptoms achieved varying degrees of improvement over the course of their 34.3 month average follow-up following surgery [16]. There was no permanent nerve damage. The follow-up period was 48 months, and none of the patients had neurologic abnormalities. The mean kyphosis angle decreased from 76° to 5°.

The main advantage of PSO technique is that it creates a wedge with support in the anterior column, thereby allowing three columns to contact when closing, and creating a better space for fusion. The correction of kyphosis shortens the spinal cord which minimizes the risk of pressure and strain injury to the spinal cord [17]. There was no nerve injury until two years after the patients' follow-up.

Although the effectiveness of this procedure has not been shown in several research, safe and successful operations need the use of competent workers and the right surgical and medical equipment.

## Conclusions

PSO can be used to achieve sagittal-plane correction and restoration of lumbar lordosis with a single posterior approach. Intraoperative complications can be prevented or the risks minimized with adequate surgical training. Most late-onset complications in PSO patients were related to instrumentation failure. As this method does not manipulate the anterior, it reduces the risk of bleeding, vascular injury and mortality.

### Abbreviations

| | |
|---|---|
| SPO | Smith-Peterson osteotomy |
| PSO | Pedicle subtraction osteotomy |
| y | Year |
| kg | Kilogram |
| m | Meter |
| min | Minutes |
| d | Day |
| ml | Milliliter |
| SD | Standard deviation |
| ICU | Intensive care unit |
| N | Number |
| CSF | Cerebrospinal fluid |

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### Author contributions

M.R. contributed as the main author with the concept of planning the study. M.M., H.K. and S.F. contributed in study design, patient selection and follow ups. P.R. and D.S.T. performed the statistical analysis and interpreted the data. H.K. and D.S.T. helped write the manuscript and M.R. mentored the edition of the final version. All authors read and approved the final manuscript.

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**Availability of data and materials**
The data that support the findings of this study are available but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [Donya Sheibani Tehrani].

## Declarations

**Ethics approval and consent to participate**
The current study was approved by the Isfahan University of Medical Sciences Ethics Committee with the code of IR.MUI.MED.REC.1397.230.

**Consent for publication**
Written consent was obtained from the families of patients to enter this study.

**Competing interests**
The authors declare that they have no competing interests.

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## Publisher's Note