

# Short fixation with a 3-rod technique for posterior hemivertebra resection in children younger than 5 years old

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## ABSTRACT

**Importance:** Congenital hemivertebra is commonly treated with posterior hemivertebra resection with bilateral transpedicular fixation. However, implant-related complications are common in children younger than 5 years old who undergo this surgical procedure.

**Objective:** To present the preliminary clinical and radiological outcomes of children younger than 5 years old treated by posterior hemivertebra resection and 3-rod fixation technique.

**Methods:** From January 2016 to December 2017, 14 consecutive patients of congenital scoliosis with 16 hemivertebrae were retrospectively reviewed, including 5 girls and 9 boys, aged between 25 and 55 months old (average, 37.6 months). All patients underwent posterior hemivertebra resection with short fixation with bilateral pedicle screws and a convex lamina hook. Surgical complications and corrective outcomes were assessed based on the clinical charts and spinal radiographs with a minimum 24-month follow-up.

**Results:** The mean Cobb angle of the main curve was 38.4° before surgery, 8.5° after surgery, and 8.7° at final follow-up. In the compensatory cranial curve, the preoperative Cobb angle of 16.8° was corrected to 8.1° postoperatively and was 10.3° at final follow-up. In the compensatory caudal curve, the preoperative Cobb angle of 15.9° improved to 5.3° postoperatively and was 7.8° at final follow-up. The segmental kyphosis was corrected from 13.5° to 0.5° and was 1.1° at final follow-up. There were no crankshaft phenomena, no proximal kyphosis, and no complications related to the instrumentation.

**Interpretation:** Posterior hemivertebra resection with instrumentation with bilateral pedicle screws and a convex lamina hook can achieve rigid fixation and deformity correction.

## KEYWORDS

Congenital scoliosis, Hemivertebra, Lamina hook, Pedicle screw

## INTRODUCTION

Hemivertebrae are caused by failure of formation on one side and result in laterally-based wedges consisting of half

of the vertebral body, a single pedicle, and a hemilamina.<sup>1</sup> They may be fully segmented, semi-segmented, non-segmented, or incarcerated.<sup>2</sup> Non-segmented and incarcerated hemivertebrae usually progressed gradually,

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while fully and semi-segmented hemivertebrae could progress rapidly since it has a normal growth plate.<sup>2</sup> Spinal deformity caused by hemivertebrae is difficult to correct with braces or casts, and often requires surgical treatment for correction.<sup>3</sup> Besides local deformity, the secondary curve will develop to promote trunk equilibration that are flexible in the beginning but become structural with time. Long fusion will be performed to include the rigid secondary compensatory curve in the adolescent period. To achieve a straight spine with a fusion as short as possible, early surgical treatment is required in most cases.

The prevalent treatment for congenital hemivertebrae is posterior hemivertebra resection with bilateral transpedicular fixation.<sup>4,5</sup> However, the incidence of implant-related complications with such treatment ranges from 5.13% to 6.03%, since the pedicle screw system for children younger than 5 years may not provide enough stability.<sup>6,7</sup> The goal of this study was to evaluate the primarily surgical outcomes of posterior hemivertebra resection with transpedicular instrumentation and convex lamina hook fixation in children younger than 5 years old.

## METHODS

### Ethical approval

This study was approved by the Ethics Committee of Beijing Children's Hospital. Written informed consent was obtained from the patients' guardians for inclusion in this study.

### Patients

From January 2016 to December 2017, 14 consecutive patients with hemivertebrae were retrospectively reviewed. All of the patients underwent posterior hemivertebra resection with short fixation with bilateral pedicle screws and a convex lamina hook. The inclusive criteria were congenital spinal deformity requiring surgical treatment (main curve more than 25°, progression of the curve more than 5° during a 6-month follow-up, and/or failure of conservative treatment); hemivertebra resection with bilateral pedicle screws and a convex lamina hook instrumentation one level above and below the hemivertebra; surgical age less than 5 years; and a minimum 2-year follow-up. Cases who had anterior approaches, previous spinal surgery, or cervical hemivertebrae were excluded from this research.

### Operative procedure

All patients were treated by posterior hemivertebra resection with pedicle screws and lamina hooks. Preoperative assessment including computed tomography scan, and magnetic resonance imaging were performed due to the high incidence of spinal cord anomalies

associated with congenital scoliosis.

After general anesthesia the patients were placed in the prone position on a radiolucent operating table. A standard midline incision was made, and sub-periosteal dissection was performed to expose the hemivertebra and the adjacent vertebra, including the lamina, transverse processes, facet joints, and the surplus rib head on the convex side of the thoracic spine. Needles were inserted into the pedicles of the hemivertebrae and the adjacent vertebrae to identify hemivertebrae by intraoperative C-Arm equipment. After taping and gentle palpation with a sounder probe, screws with an appropriate diameter and length were inserted into the pedicles. The posterior elements of the hemivertebra are removed. Resection includes the lamina, the facet joints, the transverse process, and the posterior part of the pedicle. The spinal cord and the nerve roots above and below the pedicle of the hemivertebra are identified. The remnants of the pedicle, vertebral body, and the upper and lower disks were removed completely with debridement of the vertebral endplates to bleeding bone in the osteotomies. In the thoracic spine, the rib head on the convex side was exposed and resected. The precontoured rods were placed into the screws and the deformity was gradually corrected by repeated compression and shortening of the vertebral column. Lamina hooks were placed at the proximal and distal vertebrae on the convex side, and the third precontoured rod was implanted into the lamina hooks. If any screws were found unstable before correction, a rod was first placed into the laminar hooks and compression was applied through laminar hooks.

Arthrodesis by posterior fusion was carried out with local bone after decortication. After surgery, all patients were mobilized within the first postoperative week and a rigid brace was worn to protect the spine for at least 12 weeks.

The operative time, blood loss, or any complication in the perioperative and follow-up periods were recorded. Standing posteroanterior and lateral radiographs were evaluated in the preoperative, immediate postoperative, and final follow-up periods. The coronal main curve and the proximal and distal compensatory curves were recorded. Segmental kyphosis (measured between the vertebra above the hemivertebra and the vertebra below the hemivertebra), thoracic kyphosis (measured between T5 and T12), and lumbar lordosis (measured between L1 and S1 on a sagittal plane) were recorded.

### Statistical analysis

SPSS version 21.0 for Windows (SPSS, Inc., Chicago, IL) was used for statistical analysis. Paired *t*-tests were used to analyze the difference in coronal main curve angle, proximal and distal compensatory curve angle, thoracic kyphosis, segmental kyphosis, and lumbar lordosis before surgery, after surgery, and at the latest follow-up. A *P* < 0.05 was considered as statistically significant.

**TABLE 1** Demographic and operative data of patients with congenital scoliosis underwent posterior hemivertebra resection

Patient	Sex	Age at surgery (m)	HV level	HV side	Segmentation	Fusion levels	Operation time (min)	Blood loss (mL)
1	F	54	L2/L3	Right	Semi-segmented	L2–L3	145	410
2	M	32	L2/L3	Left	Semi-segmented	L2–L3	123	120
3	F	47	T9	Right	Semi-segmented	T8–T10	152	680
4	F	26	L2/L3	Right	Fully segmented	L2–L3	120	435
5	M	30	T9, T11	Right	Fully segmented	T8–T12	176	405
6	M	52	L5/S1	Right	Semi-segmented	L5–S1	237	210
7	F	33	L4/L5	Right	Semi-segmented	L4–L5	148	195
8	M	55	L5/S1	Right	Fully segmented	L5–S1	180	150
9	M	42	L3/L4	Left	Semi-segmented	L3–L4	145	390
10	M	33	L2/L3	Right	Semi-segmented	L2–L3	142	405
11	M	25	T12/L1	Left	Semi-segmented	T12–L1	150	220
12	M	37	L2/L3	Right	Semi-segmented	L2–L3	120	410
13	F	32	T12/L1	Right	Semi-segmented	T12–L1	150	305
14	M	29	T7, T9	Left	Semi-segmented, Fully segmented	T6–T10	163	280

HV, hemivertebra; F, female; M, male.

**TABLE 2** Preoperative, postoperative, and final follow-up radiographic imaging parameters of patients with congenital scoliosis underwent posterior hemivertebra resection

Parameters	Preoperative	Postoperative	Final follow-up	Correction rate after surgery (%)	<i>P</i> (Preoperative vs. Postoperative)	<i>P</i> (Postoperative vs. Final follow-up)
Coronal plane						
Cobb angle (°)	38.4 ± 10.6	8.5 ± 7.3	18.7 ± 7.6	77.9	< 0.001	0.944
Proximal compensatory curve (°)	16.8 ± 9.2	8.1 ± 5.9	10.3 ± 6.1	51.2	0.001	0.341
Distal compensatory curve (°)	15.9 ± 8.1	5.3 ± 5.6	17.8 ± 7.3	66.7	0.004	0.319
Sagittal plane						
Segmental kyphosis (°)	13 (1.8, 22.3)	-1.0 (-14.3, 11.8)	-1.5 (-13.8, 12.5)	96.3	0.001	0.862
Thoracic kyphosis (°)	22.8 ± 8.6	25.6 ± 6.9	26.3 ± 9.5	12.3	0.224	0.825
Lumbar lordosis (°)	36.8 ± 15.7	42.0 ± 6.8	41.1 ± 10.2	14.1	0.175	0.763

The data are shown as mean ± standard deviation or median (Q1, Q3).

## RESULTS

A total of 16 hemivertebrae were resected in 14 patients (5 females, 9 males), aged from 25 to 55 months (average, 37.6 months) (Table 1). Three patients had fully segmented vertebrae, 10 had semi-segmented vertebrae, and 1 had both fully and semi-segmented vertebra. Most of the abnormal vertebrae were located on the right side, with only 4 on the left side.

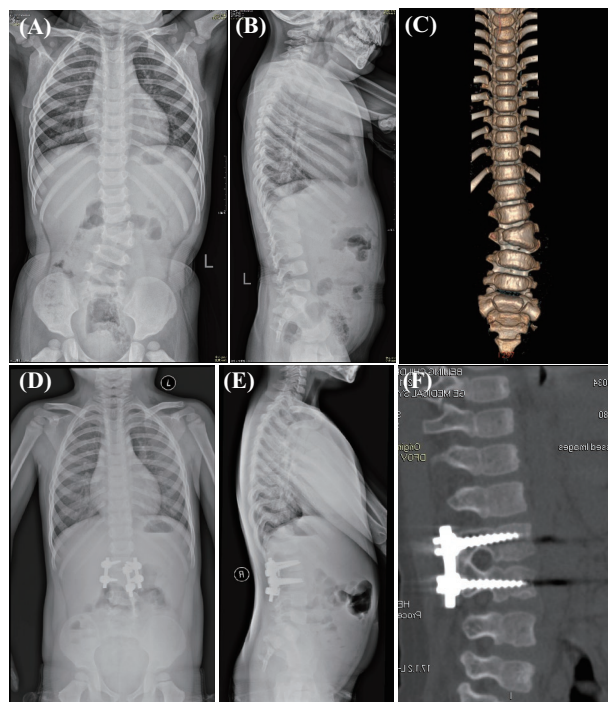
The average follow-up was 32.3 ± 4.1 months (range, 24–41 months). The mean operative time was 153.6 ± 30.1 min (range, 120–237 min) and the median estimated blood loss was 347.5 mL (range, 120–680 mL) (Table 1).

Posterior instrumentations were 4.5 mm rods with polyaxial pediatric posterior instrumentation screws and 2

convex lamina hooks directed toward each other (JNJ, Inc, Miami, FL, USA).

The correction in the coronal and sagittal planes is presented in Table 2. The mean Cobb angle of the main curve was 38.4 ± 10.6° before surgery, 8.5 ± 7.3° after surgery, and 8.7 ± 7.6° at final follow-up. In the compensatory cranial curve, the preoperative Cobb angle of 16.8 ± 9.2° was corrected to 8.1 ± 5.9° postoperatively and was 10.3 ± 6.1° at final follow-up. In the compensatory caudal curve, the preoperative Cobb angle of 15.9 ± 8.1° improved to 5.3 ± 5.6° postoperatively and was 7.8 ± 7.3° at the last follow-up. The segmental kyphosis was corrected from 13.5° to 0.5° and was 1.1° at final follow-up. The thoracic kyphosis and lumbar lordosis showed no significant changes after surgery.

There were 3 patients who required modification of the screw channel during the operation. At the last follow-up, all 3 of these patients' X-rays and CT scans showed that the correction was well maintained without any sign of implant failure, and solid fusion of the posterior elements and/or intervertebral space involved in the fusion region was noted (Figure 1).



**FIGURE 1** A 32-month-old boy with congenital scoliosis (patient #2 in Table 1) underwent posterior hemivertebra resection and 3-rod fixation. Preoperative anteroposterior (A) and lateral (B) radiographs and CT 3D reconstruction (C) showed a semi-segmented hemivertebra of L2/L3. Anteroposterior (D) and lateral (E) radiographs showed an excellent correction and sagittal CT (F) showed the solid fusion at the 2-year follow-up.

There were no major vascular or neurological complications related to the instrumentation. No pedicle breakage, pseudarthrosis, or implant failure in any of the patients was observed at the final follow-up. Also we did not find any crankshaft phenomenon, curve progression, or proximal kyphosis at the most recent follow-up.

## DISCUSSION

In cases of scoliosis secondary to hemivertebrae, the optimal surgical treatment is resection of the hemivertebra.<sup>8</sup> The originally described surgical approach for hemivertebra resection was a combined anterior and posterior approach in 1 or 2 stages. Posterior hemivertebra resection with transpedicular instrumentation was first introduced by Jürgen Harms.<sup>9</sup> Compared with anterior-posterior hemivertebra resection, posterior hemivertebra resection avoids damaging the anterior vascular and visceral structures and reduces operative time and blood loss. Currently, the 1-stage posterior hemivertebra

resection combined with bilateral transpedicular screw instrumentation has become the commonly adopted procedure for the correction of congenital scoliosis.<sup>10</sup> However, during surgical treatment of hemivertebrae, obtaining sound instrumentation and internal fixation is sometimes difficult, as vertebral bone stock is often not strong enough to allow compression forces by pedicle fixation points, especially in patients younger than 5 years.

In 2003, Ruf and Harms<sup>11</sup> reported that 5 of 28 (17.9%) children younger than 6 years old treated by posterior hemivertebra resection suffered from construct/implant-related complications. There were 2 patients with pedicle fractures and 3 with implant failures, and among them 2 additional operations were performed because of developing deformities. In 2009, Ruf et al<sup>5</sup> reported a complication rate of 21.5% and 67.9% of complications were associated with construct/implant failures. A convex pedicle was overloaded and broke in 3 patients, necessitating the inclusion of 1 additional segment into the instrumentation. In 2013, Wang et al<sup>6</sup> reported that convex pedicles were overloaded and broken in 2 patients (2/36, 5.6%), and revision surgery was indicated, necessitating the inclusion of 1 additional segment above and below into the instrumentation. In 2016, Guo et al<sup>7</sup> reported a 9.5% complication rate in 116 cases treated by posterior hemivertebra resection and 63.6% of complications were associated with the construct/implant. Pedicle misplacements in 2 patients were found postoperatively and revision surgeries were performed.

Pedicle screw stability in young children can be low against the compressive force that occurs during site closure. This may result in loosening of the pedicle screw construct, which usually occurs during the corrective procedure or during the early postoperative period. To solve the problem, Hedequist et al<sup>12</sup> proposed a posterior-only technique and implemented a 3-rod technique to achieve compression of the osteotomy site with laminar hooks and to achieve maximum stability with transpedicular instrumentation. In their series of 10 patients with an average age of 4 years and 3 months, all patients obtained fusion and there were no implant-related complications or revisions needed. The average preoperative Cobb measurement of 44° was improved to 8° at the final follow-up. They concluded that the 3-rod technique should be used in young children whose pedicles may not be able to withstand the compressive forces needed to close down the wedge resection site.<sup>12</sup>

In our study, 16 hemivertebrae in 14 children were resected and fixed with the 3-rod technique. After surgery all patients had obtained fusion with no loss of correction. There have been no cases of postoperative implant failures. Compared with the previous report,<sup>12</sup> this study indicated that the 3-rod technique was more applied to the semi-segmented hemivertebrae, since 11 of 16 hemivertebrae

were semi-segmented. According to our experience, for semi-segmented hemivertebrae, osteotomy can easily destroy the stability of the screw in the convex residual pedicle without the protection of the bony endplate. The pedicle screws combined with additional lamina hooks may offer greater strength to close the resection gap and to hold the adjacent vertebrae.

Our study had two limitations. First, this was a retrospective study with a small number of patients included; more patients and larger studies are needed in the future. However, to the best of our knowledge, this is the second study to report the application of the 3-rod technique. Second, the follow-up duration was still relatively short considering that our patients were <5 years of age and had substantial growth potential. Thus, a long-term follow-up study should be conducted in the future.

In conclusion, posterior hemivertebra resection with short instrumentation with bilateral pedicle screws and a convex lamina hook can achieve rigid fixation and deformity correction. We recommend this technique in younger patients undergoing hemivertebra excision, especially patients with semi-segmented hemivertebrae.

## CONFLICT OF INTEREST

None.

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