Case Report Posterior hemivertebra resection with a navigated drilling method for congenital scoliosis: a case report and description of surgical technique

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Abstract: The use of computer navigation in spinal surgery is gaining popularity. Although initially used in the spine for the placement of lumbar pedicle screws, this technology has expanded to facilitate placement of spinal instrumentation at virtually all spinal levels. Although previous reports have described the utility of image guidance for the placement of spinal instrumentation, its use in assisting with hemivertebra resection has not been reported on extensively. Here, we described the use of computer navigation of a high-speed drill to guide resection of a fully segmental T9 hemivertebra in a 12-year-old girl with congenital scoliosis. The segmental scoliosis was 34.4° preoperatively and 3.3° at the final follow-up visit (32 months postoperatively) and the correction rate was 91.2%, and the average segmental kyphosis was 34.7° before surgery and 19.6° at the final follow-up visit (43.6% correction rate). The mean distance between the center sacral vertical line and the C7 plumb line was reduced from 12.1 mm to 2.04 mm. This case demonstrates the use of a safe, effective technique for hemivertebra resection in congenital scoliosis. Furthermore, it illustrates a novel application of computer navigation to provide real-time three-dimensional imaging during critical osteotomies and pedicle screw insertion to avoid damage to the nervous tissue, compromise of adjacent critical vascular structures, and pedicle fracture; reduce screw loosening; and improve spinal stability while achieving satisfactory correction in children.

Keywords: Hemivertebra resection, congenital scoliosis, computed tomography navigation, navigated drill, complications

Introduction

Hemivertebra, a wedge-shaped vertebra that may lead to substantial spine deformity, is the most frequent reason for congenital scoliosis (CS). Ruf and Harms [1] reported that with the exception of some incarcerated types, the hemivertebra has growth potential similar to that of a normal vertebra, creating unacceptable deformity during further patient growth. Zhang et al. [2] demonstrated that early surgical intervention is the most effective means of preventing deformity progression and compensatory changes. At present, traditional techniques involving the use of a lamina punch and osteotome via a double (combined anterior and posterior) or single posterior approach are used to conduct hemivertebra resection (HR) [1, 3-5]. However, the incidence of surgical complications, such as neurologic deterioration, pedicle fracture, atelectasis or pleural effusion, pedicle screw breakage, and even failure in correction of intraoperative spinal deformity, is as high as 10.5-20.3% [2-4, 6-8]. Although many reports on HR have been published, few have addressed the minimization of surgical complications in children with CS. To minimize the risks of surgery in these patients, we applied a navigated high-speed drilling method (NHSDM) that facilitated screw implantation and guides HR in the treatment of CS. To our knowledge, the use of this novel technology with HR has been rarely reported.

Table 1. Patient c	haracteristics
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Sex	Age (years)	Side	Hemivertebra segment	Segmentation	FS	Complication	Follow-up (months)
F	12	R	Т9	Fs	4	Wound infection	32

FS, fused segmentation; F, female; R, right; Fs, fully segmented.



Case report

This otherwise healthy female patient presented at 12 years of age (**Table 1**). Her mother brought her to our hospital upon noticing that the girl's right shoulder was much higher than the left shoulder. The patient reported no obvious discomfort.

Examination revealed "razor back" deformity on the right side. The patient had no sensory disturbance, her muscle force and tension were normal, knee and Achilles tendon reflexes were normal, no pathologic reflex was present, and the Lasegue test and Bragard sign were negative.

Imaging demonstrated that the left shoulder was 1.2 cm higher than the right shoulder, and revealed the presence of a right, single, fully segmented hemivertebra with a wedge shape at the T9 junction (Figure 1A, 1B). At T9, the right rib was normal and the left was absent; the segmental scoliosis (T8-T10) was 34.4° and the segmental kyphosis (T8-T10) was 34.7°. The distance between the center sacral vertical line and the C7 plumb line was 12.3 mm. The patient had a Risser grade of IV. Nervous-system magnetic resonance imaging was performed to test for the presence of spinal intramedullary disease, and ultrasonic cardiography and pulmonary function tests were performed to evaluate whether heart or lung disease was present. The primary diagnosis was CS.

Surgical technique

The lesion segment was scanned using threedimensional (3D) computed tomography. Scanning was performed caudocranially with 2-mm-thick sections. The image data (in DICOM format) were imported into the navigation system used for surgical planning (on an optical disk). The navigation system reconstructed the 3D images automatically, then provided the surgeon with a multiplanar image of the hemivertebra. The surgery was planned, including determination of the appropriate length, diameter, and trajectory of the screw and the range of HR (**Figure 2A**).

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Figure 2. Screw implantation and hemivertebra resection assisted by computer navigation. A. The navigation monitor provides a dynamic display of the trajectories of surgical instruments during screw implantation. B. The instrument tracker, indicator, high-speed drill, and indicator fixed on the high-speed drill handle and connected to the instrument tracker. C. Clinical photograph of the surgeon removing the hemivertebra with a navigated high-speed drill. D. Hemivertebra resection using a high-speed drill assisted by navigation.

The procedure was performed under general anesthesia (intubation: propofol, 200 µg/kg, Fresenius Kabi Deutschland GmbH, Bad Homburg v.d.H., Germany; fentanyl, 250 µg, RenFu LLC, YiChang, China; midazolam, 2 mg; maintenance: propofol, 0.2-0.5 mg/kg/h, Enhua Pharmaceutical Limited by Share Ltd., JiangSu, China). Short-acting muscle relaxants were provided only at the time of intubation. The patient was placed in the prone position. The posterior structures of the lesion segments and neighboring vertebrae were exposed. First, a patient tracker (Stryker Leibinger GmbH & Co., Freiburg, Germany) was fixed on the spinous process of the T6 vertebra. The Navigation System II-CART II with SpineMap 3D 2.0 software (Stryker Navigation, Kalamazoo, MI, USA)

was used for the procedure. The system's C-arm tracker, patient tracker, and instrument tracker (Figure 2B) were activated, and a general instrument tracker was fixed on the high-speed drill handle using an indicator (Figure 2B). Tip and axial calibration of the high-speed drill was performed. After 190° scanning was performed at the center of the hemivertebra, 3D images of the lesion were obtained, which could be used in the process of HR and pedicle screw placement (Figure 2A).

The posterior anatomic structures of the hemivertebra, including the facet joints, lamina, transverse processes, and surplus rib head, were removed carefully using the NHSDM to expose the pedicle and nerve roots. On the



Figure 3. A. Postoperative imaging examination. The anteroposterior and lateral x-rays show good correction of the deformity. B. X-ray fluoroscopic image from the last follow-up visit shows that the spinal column sequence was good, with no curve progression during growth.

concave side, a titanium rod was installed to stabilize the spinal column before HR. The navigated high-speed drill was used to mill the residual pedicle and vertebral body (Figure 2C). Drill position and direction were guided, as visualized on the navigation screen, until the deformed structures were removed completely (Figure 2D). Then, another titanium rod was installed on the convex side. Gradual pressure was applied until the gap created by HR was closed and the nut of the pedicle screw-rod system was tight. Finally, the T8 and T10 vertebrae were fused with autogenous bone from the hemivertebra. The patient used a brace to ensure fusion and maintain stability for 3 months postoperatively.

Postoperatively, the patient was neurologically intact. She developed a wound infection, which was resolved successfully with debridement and a 2-week course of antibiotics (ceftriaxone, 2 g/24 h; Roche Pharmaceuticals, Shanghai, China). No screw loosening, pseudarthrosis formation, or curve progression at the operation site was found during the 32-month follow-up period (Figure 3A). At the final follow-up visit, the segmental scoliosis was 3.3° (91.2% correction rate) and kyphosis was 19.6° (43.6% correction rate; Figure 3B). The distance between the center sacral vertical line and the C7 plumb line was reduced from 12.32 mm to 2.04 mm. The compensatory cranial curve was improved from 26.7° preoperatively to 6.02° postoperatively and at the last follow-up visit, and the compensatory caudal curve was improved from 12.4° preoperatively to 3.4° after surgery and 3.3° at the last follow-up visit (Table 2).

Discussion

CS can lead to trunk imbalance during growth due to vertebral deformation. Most hemivertebrae have normal end-plates, which may cause deterioration deformity during growth [1, 2, 4, 9]. Although classical techniques can correct CS satisfactorily, studies of conventional methods have shown that the mean correction rate in segmental scoliosis is 33-86.1%. The mean correction rate in sagittal segments is 30-81.3%, in association with complications (**Table 3**) [1-3, 8-13]. To minimize surgical risk, we applied the novel NHSDM, which facilitates screw implantation and guides HR.

The use of a posterior surgical approach alone can avoid the complications caused by open

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Table 2. Correction in the coronal and sagittal planes

SC (°)			CC	CraC (°)	CC	CauC (°)	ę	SK (°)		TS (mm)		
Pre	Post	FU	Pre	Post	FU	Pre	Post	FU	Pre	Post	FU	Pre	Post	FU
34	2	3	26	6	6	12	3	3	34	2	3	12	2	2
SC segmental curve: CCraC compensatory cranial curve: CCauC compensatory cau-														

dal curve; TS, trunkshift; Pre, preoperative; Post, postoperative; FU, final follow up.

thoracotomy, such as ileus, pleural effusion, and abdominal hernia. The reported neurologic complication rate of this approach is 7.7% [13], compared with the rate of 28.3% for the combined anterior and posterior approach [7]. In the case described here, we adopted a single posterior approach to effectively avoid the risk of serious, potentially life-threatening, complication.

Screw implantation in children with CS is particularly challenging due to the deformity of anatomic structures [1, 2]. A meta-analysis of in-vivo studies of pedicle screw placement in patients with scoliosis showed that screw insertion was significantly more accurate with than without navigation [14]. In our case, no neurologic lesion caused by screw misplacement was detected, and we attribute this result to the use of the navigation system for preoperative planning and the guidance of pedicle screw insertion. In addition, intraoperative neurophysiologic monitoring was used.

In patients with CS, pedicle fracture is one of the most common complications caused by improper instrumentation, technical error, softness of bone cortex, and small pedicle diameter [2]. Ruf et al. [4] reported the occurrence of pedicle fracture and instrumentation failure in 7.3% each of 41 patients with CS. Hedequist et al. [15] reported that pedicles in children were too fragile to withstand the pressure of hemivertebral space closure. We agree with Crostelli et al. [16] that the major reason for pedicle fracture is technical defect. Pedicle fracture did not occur in our case, which we attribute to the accuracy of initial pedicle screw placement under navigational guidance; this technique avoided pedicle damage caused by reinsertion, which may be an important contributor to the positive outcome.

Pedicle screw loosening is another typical complication of posterior fixation, which may be related to further growth after segment fusion, spinal osteoporosis, stress shielding, and wear debris. The reported incidence of screw loosening ranges from 7% to 19.5% [17, 18]. Its prevention is crucial, as it has been linked to the occurrence of several complications, including screw breakage, pseudarthrosis, and loose correction [19,

20]. No pedicle screw loosening was observed in our case, perhaps due in part to the short follow-up period, but also due to the achievement of complete HR and correct screw implantation using the NHSDM. Furthermore, the patient used a brace to ensure fusion and maintain stability for 3 months postoperatively.

Postoperative wound infection occurred in our case, but the incision healed excellently after debridement and 2 weeks of antibiotics. Measures that can prevent infection include preoperative nutritional supplementation, intraoperative wound irrigation with warm saline solution, and, in cases of surgery lasting more than 3 hours, intraoperative transfusion of antibiotics [21, 22]. All of these measures were used in the case described here. We consider that the long duration (4.5 hours) of surgery increased the risk of infection in this case [21].

Although a positive outcome was achieved in our patient, this report has several limitations. The follow-up period was relatively short. The patient was still immature at the last follow-up visit, and curve progression may occur with further growth.

In conclusion, our results demonstrate that posterior HR using the NHSDM is a new operative technique with significant advantages. It leads to satisfactory correction in the frontal and sagittal planes, prevents pedicle fracture, and enables highly accurate pedicle screw insertion. In particular, it avoids damage to the nervous tissue and adjacent critical vascular structures. We believe that this technique is an effective and novel method for the treatment of CS.

Disclosure of conflict of interest

None.

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Deference	Publication	Nie	Mean FU	Mean age at	Approach	Segmental scoliosis			Segm	nental k	yphosis	- Complications	
Reference	year	INO.	(years)	surgery (years)	Approach	Pre (°)	FU (°)	Corr (%)	Pre (°)	FU (°)	Corr (%)	Complications	130 (70)
Holte et al. [12]	1995	37	6	12	Ant + post	54	35	35	-	-	-	8 nerve root lesions (1 permanent) 3 pseudarthroses 3 infections 6 extensions of fusion	54.1
Ruf and Harms [1]	2003	25	3.5	3.3	Post	45	13	72	22	8	63.6	3 implant failures requiring revision2 pedicle fractures2 curve progressions at operation site requiring revision1 infection and revision	32
Ding et al. [16]	2005	21	1.9	11.4	Ant + post	51.4	19.5	62.1	37.1	18.2	50.9	1 pressure sore 1 pedicle damage 1 curve elongation	14.3
Bollini et al. [3]	2006	34	6	3.5	Ant + post	40	27	33	20	14	30	5 pseudarthroses 6 curve progressions 1 transient paraparesis	35.3
Zhang et al. [2]	2011	56	2.7	9.9	Post	42.4	12.3	72.9	42	14.5	70	1 delayed wound healing 2 pedicle fractures 2 rod breakages 1 proximal junction kyphosis requiring revision	10.7
Wang et al. [10]	2013	36	5.2	4.9	Post	36.6	5.1	86.1	21.2	5.8	72.6	1 delayed wound healing 2 pedicle fractures 1 progressive deformity 4 implant removals	19.4
Qureshi et al. [15]	2015	24	5.6	17	Post	51	20	61	42	13	69	1 proximal junctional kyphosis 1 implant failure 1 transient deficit 2 wound infections	20.8
Feng et al. [8]	2016	19	3.9	5.8	Post	34.8	13.4	61.5	23.5	5.8	75.3	1 pedicle fracture 1 instrumentation failure	10.5
Guo et al. [9]	2016	39	5.4	3.5	Post	38.4	6.3	83.6	17.1	3.2	81.3	1 pedicle fracture 1 rod breakage 1 curve progression requiring reoperation	7.7

 Table 3. Summary of previous reports of surgical treatment for congenital scoliosis

FU, follow up; Pre, preoperative; Corr, correction; ISC, incidence of surgical complications; Ant, anterior; Post, posterior.

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