

# Surgical Outcomes of a New Technique Using a Convex Rod Rotation Maneuver for Adolescent Idiopathic Scoliosis

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## Abstract:

**Introduction:** Because of adolescent idiopathic scoliosis (AIS), most surgeons use rod rotation on the concave side for Lenke types 1 and 2 curves. Nevertheless, the accurate placement of pedicle screws within dysplastic pedicles, especially on the concave side, is sometimes challenging. Conversely, there is a concern that apical rotation might be exacerbated after convex rod rotation maneuver (RRM) because the rod is rotated in the same direction as vertebral rotation. This study aims to demonstrate the surgical technique and outcomes of a convex RRM with direct vertebral rotation (DVR) for the correction of AIS.

**Technical Note:** Multilevel pedicle screws were inserted into the vertebrae. The pre-bent pure titanium rod was set on the convex side and then derotated to nearly 90°. DVR was conducted for the desired vertebrae. Another pre-bent titanium alloy rod, for placement on the concave side, was contoured the same as the rod on the convex side. Using a reduction tube that allowed easier capture of the rod, the rod was connected to the concave side screws. DVR was again conducted for the desired vertebrae. Among the 59 patients, the correction rate of the main thoracic curve in Lenke types 1 and 2 AIS was 75.1% and 65.0%, respectively. The absolute value of the change in apical vertebral rotation between pre- and post-operative computed tomography (CT) scans in Lenke types 1 and 2 curves was 4.8° and 4.2°, respectively.

**Conclusions:** The convex RRM improved vertebral rotation in Lenke types 1 and 2 AIS. This procedure should be regarded as one of the surgical options for AIS, especially in patients with a narrow pedicle width on the concave side.

## Keywords:

Adolescent idiopathic scoliosis, Convex rod rotation maneuver, Correction rate, Apical vertebral rotation

Spine Surg Relat Res 2021; 5(3): 205-210

[dx.doi.org/10.22603/ssrr.2020-0185](https://doi.org/10.22603/ssrr.2020-0185)

## Introduction

In surgery for adolescent idiopathic scoliosis (AIS), several procedures have been developed to obtain subsequent correction. The modern instrumentation system, which uses the technique of correction via the concave rod rotation maneuver (RRM) advocated by Cotrel and Dubousset<sup>1)</sup>, has gained wide acceptance and popularity. The concept of concave rod rotation was introduced to obtain three-dimensional correction after scoliosis surgery<sup>1)</sup>. More than 80% of surgeons use rod rotation on the concave side for Lenke type 1 curves<sup>2)</sup>. One of the reasons for this is that, compared with the RRM starting on the convex side, the rod rotation on the concave side has the effect of pulling the concave vertebrae backward, preventing the exacerbation of apical rotation.

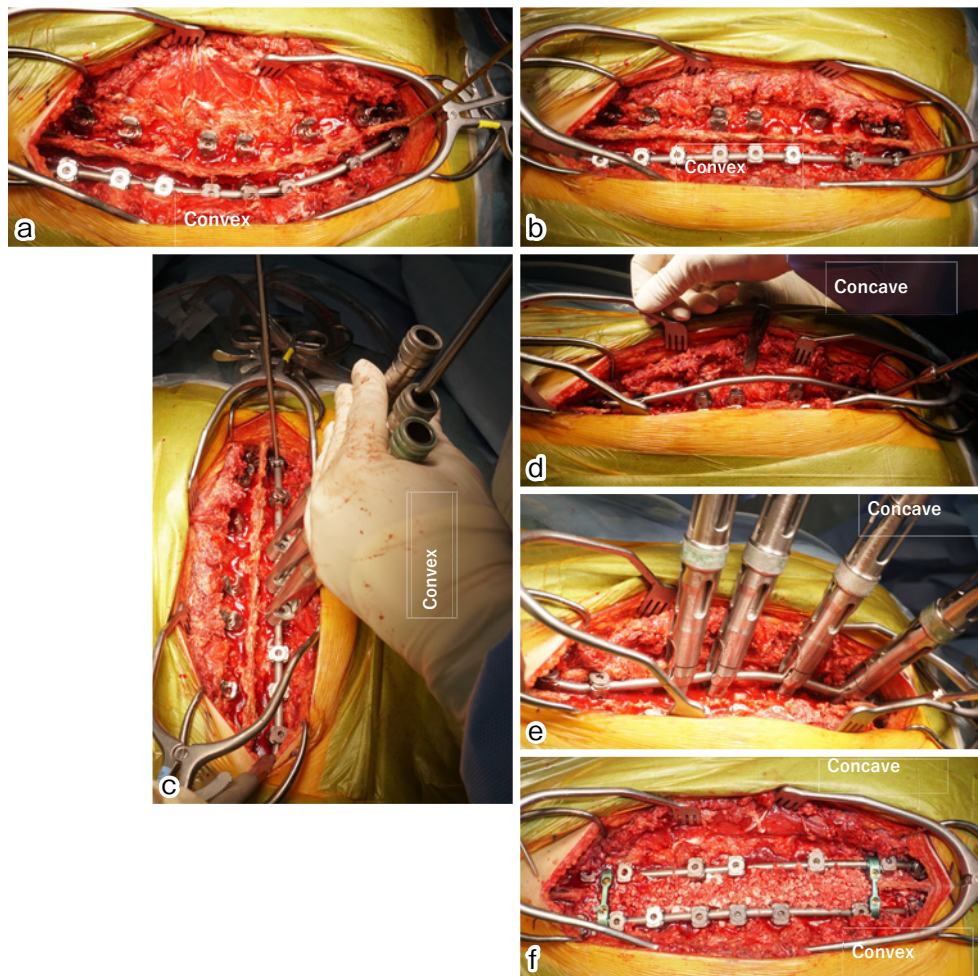
Extended use of many segmental pedicle screws (PSs) in the thoracic spine offers a reliable method of treating spinal deformities, with excellent deformity correction and a high margin of safety<sup>3)</sup>. Conversely, accurately placing PSs within dysplastic pedicles, especially on the concave side<sup>4)</sup>, is sometimes challenging.

The spinal deformity can be reduced by either rod translation or rod derotation. However, the surgeon must be mindful that the 90° rod derotation technique will exaggerate the rib prominence<sup>5)</sup>. Thus, it is helpful to manually apply a counterforce on the prominence while derotating the spine. In addition, the theoretical concern is that derotation potentially transmits forces to the lumbar spine, aggravating the torsional deformity of the lumbar spine<sup>6)</sup>. Direct vertebral rotation (DVR), which applies rotational forces to the apical

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Received: October 1, 2020, Accepted: October 31, 2020, Advance Publication: December 5, 2020

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**Figure 1.** A 6.35 mm pure titanium rod was contoured to approximately 30°. The pre-bent rod was set on the convex side (a) and then derotated to nearly 90° (b). DVR was conducted for the desired vertebrae, especially around the apex level. An in situ bender was added under careful observation of spinal motor evoked potentials (c). The pre-bent 6.35 mm titanium alloy rod was contoured as on the convex side. The rod that was overbent for thoracic kyphosis was installed to reduce rotation and create kyphosis (d). The rod was connected to the concave side screws using a reduction tube that allowed easier capture of the rod (e). DVR was again conducted for the desired vertebrae. Finally, osteotomies and bone grafting were conducted (f). None of the patients underwent costoplasty.

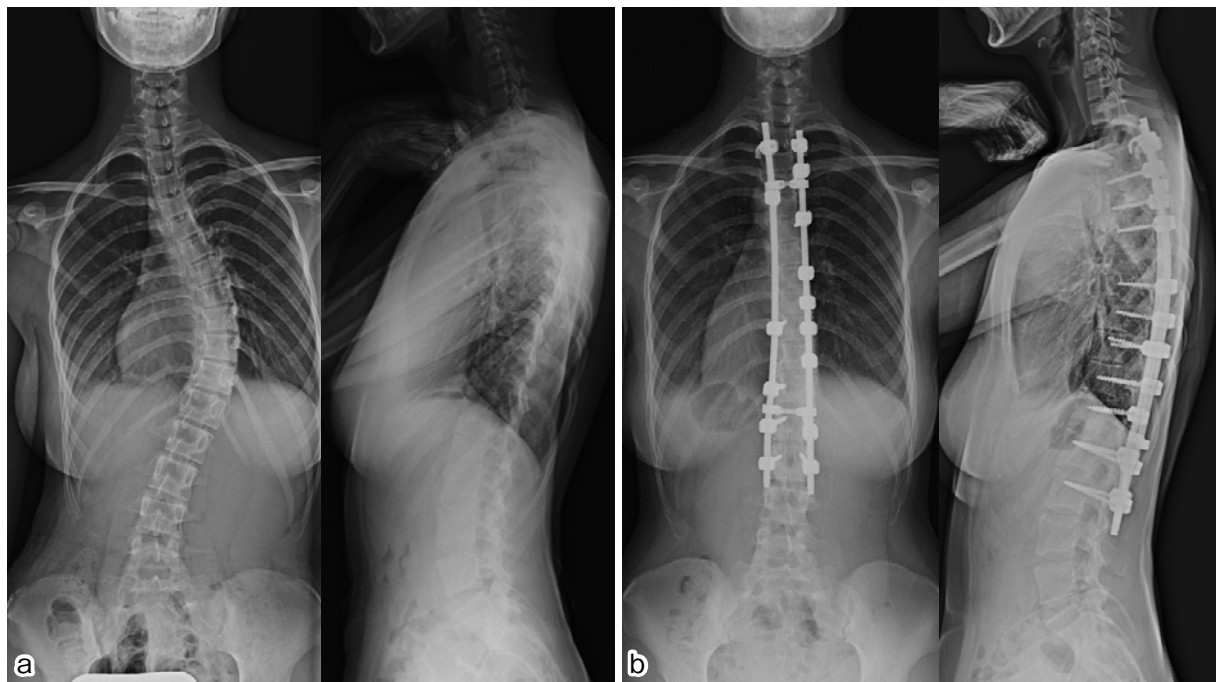
vertebrae in a direction opposite to that of rod derotation, should be used<sup>7</sup>. We previously reported a RRM starting from the convex side<sup>8</sup>. However, the effect of this technique on vertebral rotation has remained unclear. Therefore, this study aimed to demonstrate the surgical technique and outcomes of the convex rod rotation maneuver (RRM) with DVR.

### Technical Note

#### Operative technique

Segmental/multilevel PSs were inserted into the vertebrae. We preferred to use uniplanar or monoaxial screws to increase the effect of the vertebral rotation technique. A 6.35 mm pure titanium rod was contoured to approximately 30°. The pre-bent rod was set on the convex side (Fig. 1a) and

then derotated to nearly 90° (Fig. 1b). DVR was conducted for the desired vertebrae, especially around the apex level (Fig. 1c). An in situ bender was added under careful observation of spinal motor evoked potentials. Another pre-bent 6.35 mm titanium alloy rod, for placement on the concave side, was contoured the same as the rod on the convex side. A rod that was overbent to thoracic kyphosis was inserted to reduce rotation and create kyphosis (Fig. 1d). The rod was connected to the concave side screws using a reduction tube that allowed easier capture of the rod (Fig. 1e). DVR was again conducted for the desired vertebrae. The screw on the convex side at the level was partially loosened while the second DVR was conducted. Finally, osteotomies and bone grafting were conducted (Fig. 1f). None of the patients underwent costoplasty. Sublaminar tapes or other anchors on the concave side were not used on a routine basis.



**Figure 2.** A 13 year-old girl had Lenke type I scoliosis. Whole spine X-ray showed that the main thoracic curve was 50° from T5-L1, and the apical vertebra was T9 (a). Post-operative X-ray (b) showed that the scoliosis had been corrected by 12°. The thoracic kyphosis improved from 13° to 22°.

**Table 1.** Demographic Data of Patients with Lenke Types 1 and 2 Adolescent Idiopathic Scoliosis.

Variables	Mean (SD) or n (%)
Age (yr)	15.5 (3.3)
Sex (female)	52 (88%)
Lenke type	
1	47 (80%)
2	12 (20%)
Follow-up period (yr)	4.5 (2.3)
SRS-22 before surgery	
Function/activity	4.7 (0.33)
Pain	4.3 (0.50)
Self-image/appearance	2.5 (0.54)
Mental health	4.3 (0.38)
Total	4.0 (0.30)
SRS-22 at the final follow-up	
Function/activity	4.6 (0.29)
Pain	4.6 (0.53)
Self-image/appearance	4.0 (0.65)
Mental health	4.7 (0.61)
Satisfaction with management	4.1 (0.51)
Total	4.4 (0.31)
PS density	1.66 (0.28)
Adding-on	12 (20%)

SRS-22, Scoliosis Research Society outcome instrument score; PS, pedicle screws

mography (CT) images using the methods described by Ho’s method<sup>9)</sup>.

**Representative case**

A 13 year-old girl had Lenke type I scoliosis. Whole spine X-ray showed that the main thoracic (MT) curve was 50° from T5-L1, and the apical vertebra was T9 (Fig. 2a). Post-operative X-ray (Fig. 2b) showed that the scoliosis had been corrected by 12°. The thoracic kyphosis improved from 13° to 22°. Pre-operative CT showed a 10° vertebral rotation and a narrow pedicle on the left side at T9. The angle of rotation was 7° after surgery.

**Surgical outcomes**

Of the 59 patients, 52 (88%) were female and 47 (80%) had Lenke type 2 AIS (Table 1). The mean age was 15.3 yr, and the mean follow-up duration was 2.8 yr. SRS-22 self-image/appearance scores were 2.5 before surgery and 4.0 at the final follow-up. In terms of correction of coronal and sagittal planes, the Cobb angle significantly improved in MT, proximal thoracic (PT), and thoracolumbar/lumbar (T/L) regions in both Lenke types 1 and 2 AIS (Table 2). The correction rate in Lenke type 1 AIS was 75.1%, 48.6%, and 66.8% in MT, PT, and T/L regions, respectively. Table 3 compares pre- and post-operative radiological parameters to evaluate the outcomes of rotation. AVR improved significantly in both Lenke types 1 and 2 AIS. The absolute value of the change in AVR between pre- and post-operative CTs in Lenke types 1 and 2 AIS were 4.8° and 4.2°, respectively.

**Evaluation of vertebral rotation**

Apical vertebral rotation (AVR) was measured from pre-operative and immediately post-operative axial computed to-

**Table 2.** Preoperative and Postoperative Radiological Outcomes: Coronal and Sagittal Planes.

		Mean (SD) or n (%)	P-value*
<b>Lenke 1</b>			
Cobb angle			
Pre-op	MT	50.3 (7.1)	
	PT	26.3 (8.2)	
	T/L	30.9 (9.6)	
Final	MT	12.7 (6.5)	<0.001
	PT	13.5 (7.0)	<0.001
	T/L	13.5 (7.0)	<0.001
Correction rate	MT	75.1 (10.7)	
	PT	48.6 (20.1)	
	T/L	66.8 (17.8)	
Thoracic kyphosis			
Pre-op		14.7 (9.4)	
	Final	21.1 (7.3)	<0.001
<b>Lenke 2</b>			
Cobb angle			
Pre-op	MT	62.8 (13.0)	
	PT	43.1 (5.8)	
	T/L	33.3 (12.1)	
Final	MT	21.4 (5.9)	<0.001
	PT	23.3 (6.9)	<0.001
	T/L	11.0 (5.9)	<0.001
Correction rate	MT	65.0 (10.5)	
	PT	45.3 (16.7)	
	T/L	64.5 (17.3)	
Thoracic kyphosis			
Pre-op		20.8 (13.0)	
	Final	22.7 (5.4)	0.514

MT, main thoracic; PT, proximal thoracic; T/L, thoracolumbar/lumbar;  
 \* The paired t-test was used for comparison of presurgical and postsurgical radiological parameters.

### Discussion

Recently, many newer instrumentation techniques, including DVR<sup>7)</sup>, cantilever bending technique<sup>6)</sup>, differential rod contouring<sup>10)</sup>, bilateral vertebral coplanar alignment maneuver<sup>11)</sup>, simultaneous double-rod rotation technique<sup>12)</sup>, and simultaneous translation<sup>13)</sup>, have been developed to gain three-dimensional reduction of scoliosis. In terms of the coronal correction rate, our procedure showed a coronal correction similar to that of recent papers that showed an approximately 70%-80% correction rate<sup>5,7,12-20)</sup>. Additionally, regarding changes in the sagittal profile, this procedure preserved the kyphosis to the same extent as that of previous studies that used concave maneuvers<sup>7,13,14,16,18,20-23)</sup>. In previous studies, post-operative thoracic kyphosis ranged from 22° to 34°. The thoracic kyphosis with our technique showed similar results. However, the change in rotation before and after surgery with convex RRM is unclear. This is the first study to reveal changes in the degree of rotation after the procedure.

The correction of rotation is essentially one of the important goals of surgery for AIS. Lee and Suk et al.<sup>7)</sup> demon-

**Table 3.** Preoperative and Postoperative Radiological Outcomes: Apical Vertebral Rotation and Translation.

		Mean (SD)	P-value*
Apical vertebral rotation (degrees)			
Lenke type 1			
Pre-op		13.0 (6.8)	
	Post-op	8.6 (8.9)	
Δ		4.8 (4.4)	<0.001
Lenke type 2			
Pre-op		15.6 (7.0)	
	Post-op	11.4 (6.1)	
Δ		4.2 (6.0)	0.036
Apical vertebral translation (mm)			
Lenke type 1			
Pre-op		41.8 (13.1)	
	Post-op	6.6 (9.7)	
Δ		35.2 (13.5)	<0.001
Lenke type 2			
Pre-op		46.0 (18.3)	
	Post-op	8.7 (7.6)	
Δ		37.4 (15.3)	<0.001

\* The paired t-test was used for comparison of presurgical and postsurgical radiological parameters.

strated that better correction of axial rotation also achieved better coronal correction. Di Silvestre et al.<sup>22)</sup> reported that DVR obtained significantly better correction of AVR at follow-up and a significantly greater final correction of the MT curve in comparison with simple concave rod rotation. In addition, Chang et al.<sup>20)</sup> demonstrated that post-operative apical and end vertebral rotation values were significantly associated with patient satisfaction in long-term follow-up. Therefore, it is important to evaluate the rotation achieved by the surgical procedure, although this has not been evaluated previously. Lee et al.<sup>7)</sup> showed that the average pre-operative AVR of 16.7° was corrected to 9.6° in the DVR group, indicating a 42.5% correction, whereas the correction was negligible in the simple rod derotation group, decreasing from 16.1° to 15.7° (2.4%). Di Silvestre et al.<sup>22)</sup> also showed a significantly better final correction of AVR with DVR (DVR group 63.4% vs. No-DVR group 14.8%, p<0.05). Faldini et al.<sup>22)</sup> reported that a corrective maneuver simultaneously using two differently contoured rods combined with DVR can provide a good triplanar deformity correction (AVR decreased from 25.3° to 9.7°, p<0.05, 61.7% correction). Our procedure also showed significant correction of AVR (37% correction in Lenke type 1 AIS and 27% correction in Lenke type 2 AIS).

Seki et al.<sup>24)</sup> investigated the contributions of rod contouring and differential rod contouring on the reduction of apical axial vertebral body rotation. They mentioned that a difference of >10° between concave and convex apical rod curvatures predicts substantial derotation. In their study, the mean AVR angle was 15.4° after concave rod rotation, reducing further to 9.4° after subsequent convex differential rod contouring (p<0.001). Our concept was similar to theirs.

After the initial placement of a 6.35 mm pure titanium rod on the convex side, a 6.35 mm titanium alloy rod was put on the concave side to reduce the rotation and gain kyphosis. Conversely, the RRM requires stable anchors at the apical vertebrae on the concave side of the curve. The results of posterior instrumentation using apical fixation with hooks or sublaminar wires was inferior to periapical screws on the concave side in the correction of rotation of AIS in a previous study<sup>25</sup>. Thus, our procedure might be an option for patients with a pedicle width on the concave side that is too narrow to insert a PS.

Several advantages of initial convex side manipulation have been previously described<sup>8,26</sup>. First, pre-bent rods can be applied more easily on the convex side because the curvature is less pronounced than on the concave side. Second, this maneuver involves the placement of convex PSs, which have a lower risk of pedicle wall penetration because of their larger diameter. In addition, longer PSs can be used on the convex side. Densely placed screws are advantageous in the manipulation process because each screw is subject to less load than are smaller screws that are less densely placed. Third, the distances between the PSs are greater on the convex side than those on the concave side, which is advantageous for spinal manipulation techniques, such as derotation or an in situ bending maneuver, because the spine can be manipulated with less load following the principles of leverage. Finally, a medial or lateral pedicle wall breach on the convex side does not bring the screw into direct contact with the neurological structures or anterior vascular structures, respectively.

To conclude, the convex RRM improved vertebral rotation in Lenke types 1 and 2 AIS. This procedure should be considered as one of the surgical options, especially for patients with a narrow pedicle width on the concave side.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

**Ethical Approval:** This work has been approved by the Institutional Review Board of Osaka City University (No. 3170).

**Informed Consent:** Owing to the retrospective design and anonymization of patient identifiers, no informed consent was required.

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