Comparison of Surgical Results of Direct Vertebral Rotation with those of Simple Rod Derotation for Correction of Adolescent Idiopathic Scoliosis

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Background: *Adolescent idiopathic scoliosis (AIS) is abnormal spinal alignment in 3 planes: the coronal, sagittal and rotational planes, and one of the methods used for its treatment is surgical correction. In the present day, the most common surgical techniques used to correct spinal alignment are simple rod derotation and direct vertebral derotation.*
Objective: *To compare spinal alignment results after surgical correction with simple rod derotation and direct vertebral derotation.*
Material and Method: *We retrospectively enrolled 29 AIS patients who had undergone surgical correction using simple rod derotation or direct vertebral derotation at Rajavithi Hospital, Bangkok, Thailand between January 2012 and December 2014.This study was conducted by a single surgeon, and the surgical technique was chosen according tothe surgeon's preference. X-ray and CT scan of whole spine were used by an interobserver to measure parameters such as apical vertebral rotation angle, coronal and sagittal vertebral alignment, lower instrument vertebral tilt and shoulder balance,and to compare the results of the two groups.*
Results: *There was a significant improvement in overall spinal alignment parameters postoperatively in both groups, but there was no significant difference in apical vertebral rotation or thoracic kyphosis in the simple rod derotation group. There was no significant difference between overall spinal alignment of the two groups.*
Conclusion: *Both surgical techniques showed improvement in overall spinal alignment; however, no significant difference between these improvements was found in the two groups.*

Keywords: *Adolescent idiopathic scoliosis, Surgical correction, Simple rod derotation, Direct vertebral rotation*

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Adolescent idiopathic scoliosis (AIS) is an abnormality of spinal alignment in 3 planes: the coronal, sagittal and rotational planes, and its overall prevalence is 3% of the population. The causes of scoliosis are unknown, and the risk factors of AIS remain unclear, but it is more commonly found in females (female:male ratio 7: 1). The various methods of treatment include close observation, orthosis, and surgery, depending on the degree of deformity. Surgical indications are severe curve (usually Cobb angle of more than 45 degrees), curve progression, thoracic hyperlordosis, pain, and cosmetic factors[1]. One method of surgical treatment is fusion of minimal numbers of vertebra and 3D correction. In the past, Harrington rod provided correction in coronal plane deformities but not in flat back or sagittal plane ones. In 1980, Cotrel et al[2] used rods with posterior multiple anchor and achieved better correction in both the coronal and sagittal planes. Nowadays, in Thailand and worldwide, surgeons are using pedicular screw with rod derotation because of its better results in all 3D planes. A novel modern maneuver, direct vertebral derotation, has been reported as achieving ultimate rotational correction. In 2004,Se Il Suk et al[3-5] used unipedicular grip for direct vertebral derotation and found better spinal alignment with this technique. At present, there is ongoing development of instruments for use in improvement of surgical correction, such as vertebral column manipulation instruments (VCM; Medtronic, Minneapolis, MN). VCM uses bipedicular grip, but there is no evidence from previous studies to compare simple rod derotation with bipedicular grip direct vertebral

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derotation.

Material and Method

Twenty-nine AIS patients were retrospectively enrolled who had undergone surgical correction using simple rod derotation (Fig. 1) or the direct vertebral derotation technique utilizing vertebral column manipulation instruments (VCM; Medtronic, Minneapolis, MN) (Fig. 2) at Rajavithi Hospital, Bangkok, Thailand between January 2012 and December 2014. Surgical correction was performed by a single surgeon, and the technique used was chosen according to the preference of the physician (a senior spine surgeon). All participants' preoperative and post-operative plain radiograph (x-ray) and computer tomography (CT) scan of whole spine were reviewed by an interobserver (a junior spine surgeon). Angle measurement using Synapse Pacs program included apical vertebral rotation angle, coronal alignment, thoracic Cobb angle, lumbar Cobb angle and sagittal vertebral alignment (thoracic kyphosis), lower instrument vertebral tilt, and shoulder balance (Fig. 3-6). Inclusion criteria were AIS patients who had undergone surgical correction using the simple rod derotation or direct vertebral derotation techniques, and had had x-ray and CT scan pre- and post-operatively. Exclusion criteria were patients who underwent surgical correction with both anterior and posterior approach.

Surgical technique [6]

After intubation and application of intraoperative neuromonitoring, the patient was turned to the prone position. Using the standard midline posterior approach, the skin was incised, and the dissection in the midline was deepened using electrocautery through the superficial and lumbodorsal fascia to the tips of the spinous processes. The posterior elements were exposed subperiosteally by reflecting the erector spinae muscle laterally to the tips of the transverse processes distal to proximal using electrocautery and periosteal elevators to detach the muscles from the posterior elements. Each segment was packed with gauze immediately after exposure in order to lessen bleeding, and self-retaining retractors were inserted.The bony landmark was identified: spinous process, lamina, facet joint, pars interarticularis, pedicle and transverse process.The required level was identified (depending on surgeon's preference and according to Lenke classification) with a fluoroscope, and a pedicle screw was inserted. This level and the position of the screw were confirmed using a fluoroscope after which the correction process, depending on surgeon's preference, was commenced.

The rod derotation technique was started by loosening the set screw after which a contoured rod was applied to the concavity of the curve using multiple rod holders (Fig. 1). The rod was then rotated towards

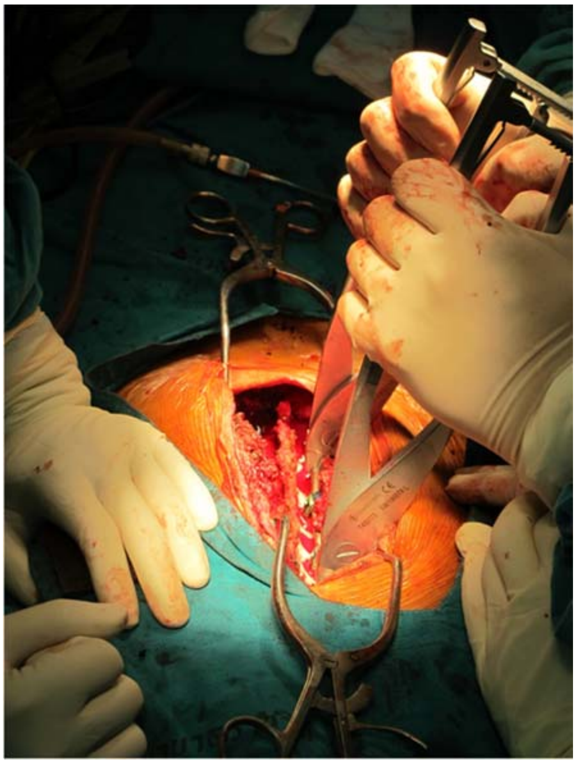

Fig. 1 Intraoperative simple rod derotation technique.

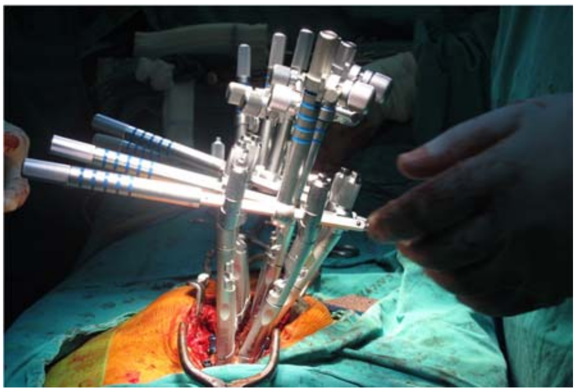

Fig. 2 Intraoperative direct vertebral rotation technique by after applying pedicle screw.

the concavity of the curve: this exerts a powerful postero-medialization pull on the apical vertebrae which is translated and rotated toward the midline as well as posteriorly. Then convex rod and set screws were applied.

The technique of DVR was started by placing the tube derotators on both concave and convex sides of the curve. The vertebral column manipulator (VCM) is a versatile apparatus which, when assembled, resembles an external fixator (Fig. 2). The concave and convex screws were connected to each other by preloaded bridge nuts at the cephalad ends of the implant holders, completing the triangulation. In flexible curves, corrective forces were applied through a single triangulated segment, but in larger or stiff curves, a quadrilateral frame was created by connecting the triangulated apical and juxtaapical vertebrae. Forces were applied through handles: the superior handle was connected vertically up from the middle of the cross connector, and the convex one was attached horizontally on the convex side end of the cross connector. Once the assembly was in place, the introduction of the concave side rod, which is prebent to conform to the normal sagittal profile, was started. The most cephalad screw was gradually lowered, and each segment was engaged by applying derotational forces through the handles. With continued derotational and translational forces, all the segments were captured into the rod to recreate spinal alignment. This method could arguably be described as the current state-of-the-art technique for scoliosis correction, even though there may not be universal consensus in this regard.

After correction, assessment was done with intraoperative neuromonitoring, using a fluoroscope to evaluate the degree of correction and leveling of the shoulder.

Radiographic measurement[6]

In accordance with Lenke classification for adolescent idiopathic scoliosis, using the PA view of whole spine radiographs, the proximal thoracic (PT), main thoracic (MT) and thoracolumbar/lumbar (TL/L) curves were identified, depending on the location of the apex (the vertebrae with most deviation from the midline of the body). The main thoracic apex includes T3 distal to T11-T12 discs. The thoracolumbar/lumbar apex includes T12-L1 discs distal to L4. The major curve was the largest Cobb measurement using the upper most and lower most tilting vertebrae endplates compared with apex vertebrae, and the other two

Fig. 3 Measurement of Apical vertebral rotation angle CT spine axial view.

Fig. 4 Measurement of Thoracic curve by Cobb angle, using the most tilting of upper vertebrae to the most tilting of lower vertebrae in whole spine radiograph PA view.

regions were designated as minor curves. In this study, we identified the thoracic Cobb angle as the main thoracic curve, and the lumbar Cobb angle (Fig. 4). Lower instrument vertebral tilt was identified on the PA view of whole spine radiographs by measuring the angle between the lower endplate of the lower instrument vertebrae and comparing it with a horizontal line (Fig. 6). This angle was not the normal cutoff. Shoulder balance was measured by comparing the levels of each shoulder. On the lateral view of whole spine radiograph, we measured thoracic kyphosis using the angle between upper endplate T5 to the lower endplate of T12 (Fig. 5).Computer tomography (CT) scans were using for evaluation of apical vertebral rotation (Fig. 3). As previously described, we identified the major curve and its apex. On the axial view of the CT scan, the apex vertebrae were identified, a line was drawn from the middle of the vertebral body to the spinous process, and the apical vertebral rotation was taken as the angle between this line and horizontal line.

Statistical analysis

Sample size calculation was based on the formula of two independent proportionsusing 1-tail alpha equal 0.05 and power 80% (π_1= 0.425was the percentage of average rotational correction of the apical vertebra in the DVR group and π_2= 0.24was the percent of average rotational correction of the apical vertebra in the SRD group)[4]. The sample size of each group was 16 patients

Baseline characteristics were described as number (percentage), and mean ± standard deviation

Fig. 5 Measurement of Sagittal alignment measuring angle from upper endplate of T5 vertebrae to lower endplate of T12 vertebrae in whole spine radiograph lateral view.

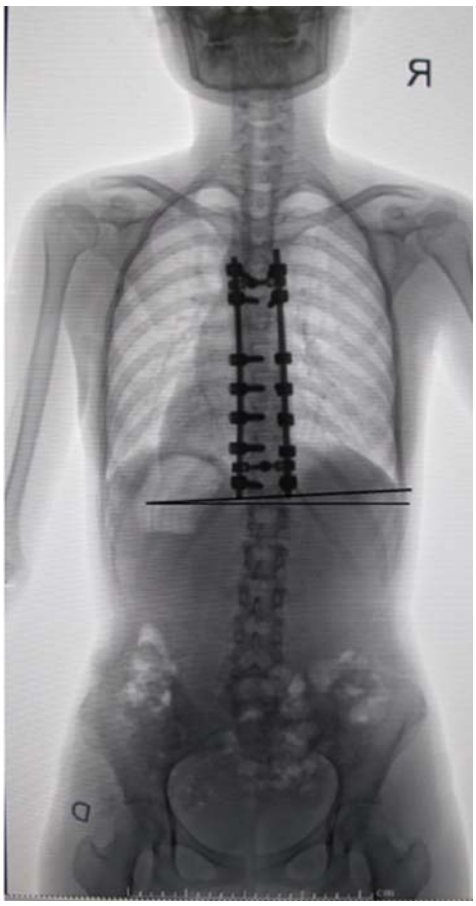

Fig. 6 Measurement of the lower instrument vertebral tilt on the PA view of whole spine radiographs, measuring the angle between lower endplate of lower instrument vertebrae compared with a horizontal line

(SD). Student t-test was used for quantitative variables, and Mann Whitney U test was used for non-normal distributions with significance set at *p*-value <0.05 using SPSS program, version 17.0.

Results

29 patients were enrolled, 13 of whom underwent surgical correction usingthe simple rod derotation (SRD) technique while the other 16 had surgical correction with the use of vertebral column manipulation instruments (VCM; Medtronic, Minneapolis, MN). The baseline demographics of the two groupsare shown in Table 1, and no statistically significant differences were found between the data of the two groups. Preoperative parameters were measured by an interobserver (a junior spine surgeon) using the program Synapse Pacs as shown in Table 2. The characteristics showed no significant difference between any of the parameters, measured in degrees, in the SRD and VCM groups.

In the SRD group, there were significant differences between preoperative and postoperative thoracic Cobb angle, lumbar Cobb angle and lower instrument vertebral tilt, but no significant differences in thoracic kyphosis or apical vertebral rotation were found (Table 3).

In the VCM group, there were significant differences between preoperative and postoperative thoracic Cobb angle, lumbar Cobb angle, lower instrument vertebral tilt and apical vertebral rotation, but no significant difference in thoracic kyphosis (Table 4).

Table 1. Baseline Demographic data

Demographic data	SRD (n = 13)	VCM (n = 16)	*p*-value
Age of onset (years)	12.1+1.3	11.9+1.4	0.796
Age at surgery (years)	14.8+1.7	15.8+1.8	0.825
Sex F:M	10: 3	14: 2	-
Weight (kg)	39.8+0.8	43.4+0.7	0.638
Height (cm)	154+1.8	157+1.6	0.731

Simple rod derotation (SRD) n = 13, Vertebral column manipulation (VCM) n = 16
Values are presented as mean + SD.

Table 2. Preoperative mean radiographic measurement

Preoperative radiographic parameters	SRD (n = 13)	VCM (n = 16)	*p*-value
Thoracic Cobb angle	57.38+29.56	50.31+12.03	0.895
Thoracic kyphosis	25.08+18.54	26.38+14.12	0.693
Lumbar Cobb angle	40.62+21.86	34.50+11.89	0.553
Lower instrument vertebral tilt	23.08+10.41	20.81+5.23	0.538
Apical vertebral rotation	19.46+13.09	15.31+5.42	0.312

Values are presented as mean + SD.

Table 3. Simple Rod Derotation group

Radiographic parameters	Preoperative	Postoperative	*p*-value
Thoracic Cobb angle	57.38+29.56	13.85+16.23	0.001*
Thoracic kyphosis	25.08+18.54	27.92+9.87	0.401
Lumbar Cobb angle	40.62+11.95	9.31+13.43	0.001*
Lower instrument vertebral tilt	23.08+3.00	5.23+3.22	0.002*
Apical vertebral rotation	19.46+6.31	12.08+8.83	0.108

Values are presented as mean + SD, * Significant at $p<0.05$

Table 4. Vertebral Column Manipulation group

Radiographic parameters	Preoperative	Postoperative	*p*-value
Thoracic Cobb angle	50.31±12.03	11.06±8.10	<0.001*
Thoracic kyphosis	26.38±14.12	24.81±6.79	0.453
Lumbar Cobb angle	34.50±11.89	6.19±6.70	<0.001*
Lower instrument vertebral tilt	20.81±5.23	3.44±2.68	<0.001*
Apical vertebral rotation	15.31±5.42	7.12±3.90	0.001*

Values are presented as mean ± SD, * Significant at $p<0.05$

Table 5. Postoperative mean radiograph measurements

Postoperative radiographic parameters	SRD (n = 13)	VCM (n = 16)	*p*-value
Thoracic Cobb angle	13.85±16.23	11.06±8.10	0.809
Thoracic kyphosis	27.92±9.87	24.81±6.79	0.153
Lumbar Cobb angle	9.31±13.43	6.19±6.70	0.508
Lower instrument vertebral tilt	5.23±3.22	3.44±2.68	0.122
Apical vertebral rotation	12.08±8.83	7.12±3.90	0.094

Values are presented as mean ± SD.

Table 6. Percentage of correction preoperatively and postoperatively

Radiographic parameters	SRD (n = 16)	VCM (n = 13)
Thoracic Cobb angle	76.0	78.1
Thoracic kyphosis	11.3	5.9
Lumbar Cobb angle	77.1	82.1
Lower instrument vertebral tilt	77.4	83.5
Apical vertebral rotation	37.9	53.5

Values are presented as percentage (%)

There were no significant differences between any of the parameters (Table 5) in the two groups. Both groups showed improvement in all parameters, and a comparison of the percentage of correction in the two groupsis shown in Table 6.

Discussion

Adolescent Idiopathic Scoliosis (AIS) is an abnormal spinal alignment in the 3D plane. In axial plane deformity, vertebral rotation is difficult to measure using plain radiograph. Aaro et al(7), used computer tomography (CT) scan to measure vertebral rotation in scoliosis. Vertebral rotation was measured using the axial plane, and CT scans found that the simple rod derotation technique achieved minimal correction. Krismer et al(8), found that rotation deformity can be slightly corrected by Cotrel-Dubousset instrumentation, but the differences were not statistically significant. Lenke et al(9), found that rotation deformity can be corrected by a mean of 11 degrees using Cotrel-Dubousset instrumentation for adolescent idiopathic scoliosis. Labelle H et al(10) compared preoperative and postoperative three dimensional reconstruction with Cotrel-Dubousset instrumentation, and they found improvements in all planes but without statistical significance. In 2004, Se I1 Suk et al(3-5) used a new technique for three-dimensional deformity correction using a unipedicular grip vertebral column manipulator, and they found a significant difference between apical vertebral rotation in simple rod derotation and the direct vertebral rotation technique.

At present, there is ongoing development of instruments for use in helping to improve surgical correction, such as vertebral column manipulation instruments (VCM). The principal of VCM based on a powerful bipedicular grip and multiple point attachments enabling correction of deformity in the 3 planes.

This study showed improvement in apical vertebral rotation in the VCM group but no improvement in the SRD group, and this may have been because the bipedicular vertebral column manipulator was a more effective instrument for obtaining correction in the rotational plane.

Improvements in other parameters were found in both groups, but there was no significant difference between the improvements achieved by the 2 techniques. This might suggest that simple rod derotationis equally effective as vertebral column manipulation in correcting the coronal and sagittal planes, but the results may have been affected by patient selection by the surgeon, who preferred that each patient's spinal flexibilities not be measured, and this could have affected the difficulty ofthe surgical correction technique.

The main limitation of this study was its small sample size. If the sample size had been larger, it might have shown differences between the two methods of treatment; furthermore, this was a retrospective study with many confounders such as patient selection bias and skill of surgeon. These limitations should be taken into account in further studies.

Conclusion

This research confirmed the results of the study of Se Ill Suk which reported that VCM corrected rotational plane more effectively than SRD; however, the latter still showed potential in correcting in the coronal and sagittal planes. As the improvements obtained by the two techniques were not significantly different, the selection method of treatment should made taking into account surgeon's preference, surgeon's skill, and cost.

What is already known in this topic?

The unipedicular grip direct vertebral rotation surgical correction technique corrects rotation deformity more effectively than the simple rod derotation technique.

What this study adds?

The bipedicular grip direct vertebral rotation surgical correction technique achieves slightly more correction of rotation deformity than the simple rod derotation technique.

Potential conflicts of interest

None.

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การเปรียบเทียบผลลัพธ์วิธีการผ่าตัดโดยใช้ Simple Rod Derotation กับ Direct Vertebral Rotation ในการผ่าตัดผู้ป่วยที่เป็นโรคกระดูกสันหลังคด

ธนิตา ปัญญาอมรวัฒน์, อธิคม เมธาเธียร, เอกภพ ภัทรพงศานติ์

ภูมิหลัง: *โรคกระดูกสันหลังคดในวัยรุ่นเป็นความผิดปกติของกระดูกสันหลังทั้ง 3 มิติ ได้แก่ แนว coronal, แนว sagittal, และแนว rotational หนึ่งในวิธีการรักษาคือการผ่าตัดเพื่อแก้ไขแนวของกระดูกสันหลัง ซึ่งในปัจจุบันการผ่าตัด ที่ทำกันส่วนใหญ่ในปัจจุบัน ได้แก่ การผ่าตัดโดยใช้ simple rod derotation กับการผ่าตัดโดยใช้ direct vertebral rotation*

วัตถุประสงค์: *เพื่อศึกษาเปรียบเทียบแนวกระดูกสันหลังหลังจากได้รับการผ่าตัดด้วยวิธี simple rod derotation และวิธี direct vertebral rotation by vertebral column manipulation (VCM)*

วัสดุและวิธีการ: *ศึกษาผู้ป่วยโรคกระดูกสันหลังคดในวัยรุ่น 29 คน ที่ได้รับการผ่าตัดแก้ไขแนวกระดูกสันหลังโดยวิธี simple rod derotation และวิธี direct vertebral rotation ในโรงพยาบาลราชวิถีกรุงเทพมหานคร ตั้งแต่ มกราคม พ.ศ. 2555 ถึง ธันวาคม พ.ศ. 2557 ผ่าตัดโดยแพทย์ 1 คน เป็นผู้เลือกวิธีการผ่าตัด โดยการวัดผล ด้วยภาพรังสีกระดูก สันหลัง และภาพเอ็กซเรย์คอมพิวเตอร์กระดูกสันหลังได้แก่ มุม apical vertebral rotation, coronal และ sagittal vertebral alignment, lower instrument vertebral tilt และ shoulder balance โดยเปรียบเทียบในแต่ละกลุ่ม*

ผลการศึกษา: *มีความแตกต่างอย่างมีนัยสำคัญในการผ่าตัดแก้ไขแนวกระดูกสันหลังโดยรวมระหว่าง ก่อนและหลังผ่าตัดในทั้ง 2 วิธี แต่ไม่มีความแตกต่างของมุม apical vertebral rotation ในกลุ่ม simple rod derotation และไม่มีความแตกต่างอย่างมีนัยสำคัญในแนวกระดูกสันหลังโดยรวมเมื่อเทียบกันทั้ง 2 กลุ่มเมื่อเทียบกัน ระหว่างก่อนและหลังผ่าตัด*

สรุป: *การผ่าตัดทั้ง 2 วิธี สามารถแก้ไขแนวกระดูกสันหลังโดยรวมให้ดีขึ้นได้โดยไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ*