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ORIGINAL ARTICLE

Selective posterior thoracic fusion by means of direct vertebral derotation in adolescent idiopathic scoliosis: effects on the sagittal alignment

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Abstract The objectives of this retrospective study were to evaluate the effect of direct vertebral derotation on the sagittal alignment of the spine after selective posterior thoracic fusion for Lenke Type I adolescent idiopathic scoliosis (AIS). Preservation of the sagittal alignment has become critical in the management of spinal deformity. Better coronal and rotational corrections in posterior selective thoracic fusion for AIS have been reported with direct vertebral derotation as compared with the simple rod rotation technique. A greater lordogenic effect has been anticipated with direct vertebral derotation; however, data comparing those two techniques in terms of correction in the sagittal plane are still lacking. Standing full-spine PA and standard lateral serial X-rays of a total of 30 consecutive patients with adolescent idiopathic scoliosis treated between 2002 and 2008 at a single institution were evaluated. All the patients had Lenke Type I curves and underwent selective posterior thoracic fusion with pedicle screw instrumentation. Patients who were treated with additional osteotomies and concave or convex thoracoplasty or concomitant anterior releases were excluded. Minimum follow-up period was 24 months. Preoperative and postoperative coronal and sagittal spinal alignments in both the groups were compared. In 13 patients, the correction was achieved by means of a simple rod rotation (SRR). In 17 patients, the technique of direct vertebral derotation (DVD) was used. Scoliosis correction averaged 67 and 69%, respectively, and was similar in both groups ($p > 0.05$). Thoracic kyphosis and lumbar lordosis remained unchanged in the SRR group ($p > 0.1$). In the direct vertebral derotation group, a significant decrease of both thoracic kyphosis and lumbar lordosis of 8.1° and 11.8°, respectively, was observed ($p < 0.0001$). Global sagittal balance remained within normal limits in all the patients at the latest follow-up. Decrease in thoracic kyphosis and lumbar lordosis should be taken into account when using direct vertebral derotation for selective posterior thoracic fusion in AIS. In order to preserve sagittal alignment in these patients, ultra hard rods or maneuvers that pull posteriorly the concave side of the spine, thus avoiding the application of additional flattening forces should be considered.

Keywords Direct vertebral derotation · Sagittal alignment · AIS

Introduction

Selective posterior fusion is currently widely used for the surgical treatment of Lenke Type I adolescent idiopathic scoliosis (AIS). In the early years of instrumented spinal fusion, attention was focused on the correction in the coronal plane. However, recent studies focused on the importance of the sagittal alignment for the preservation of physiologic posture and long-term spinal health [1, 2]. Thus, achieving the harmonious sagittal balance has become critical in the treatment of AIS. The original technique for curve correction comprises 90° simple rod rotation (SRR) with concomitant distraction on the concavity [3]. Good results have been reported in the coronal and in the sagittal plane [4]; however, rotational correction has been limited [5].

Recently, the technique of direct vertebral derotation (DVD) has been introduced [6]. In this technique, an

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additional corrective maneuver is applied directly to the apical and the juxta-apical vertebral bodies through the pedicle screws. The derotational forces are applied in a direction opposite to the spinal rotational deformity and opposite to the rod rotation. Better results especially in terms of apical rotational correction, have been reported with this technique as compared to simple rod rotation [6]. However, a greater hypokyphotic effect has been anticipated [7].

The effects on the sagittal profile after applying DVD have not been well studied.

Materials and methods

This is a retrospective study on patients with adolescent idiopathic scoliosis treated by selective posterior instrumentation and fusion at a single institution.

A total of 30 consecutive patients with Lenke Type 1 curves were treated between 2002 and 2008 by selective posterior only fusion. Pedicle screw instrumentation with a 5.5-mm titanium rod was used in all the cases. Patients who had additional osteotomies, concave or convex thoracoplasty or concomitant anterior release were excluded. Until 2005, the technique of simple rod rotation and distraction on the concavity (SRR) as originally described by Cotrel and Dubousset was used [3]. In 2006, the DVD maneuver as described by Lee et al. [6] was added to the surgical technique. Serial standing X-rays in the PA and in the standard lateral projection were used for preoperative and postoperative evaluation. Curve magnitude in the coronal plane was measured between the end vertebrae. Coronal balance (CB) was measured as the distance between C7 plumb line and the central sacral vertical line (C7PL-CSVL). Thoracic kyphosis (TK) was measured between Th 5 and Th 12, and lumbar lordosis (LL)—between Th 12 and L 5. Sagittal balance (SB) was measured between C7PL and the posterior edge of S 1. Paired samples t test was used for statistical evaluation. The level of significance was set at $p < 0.05$.

Results

Demographic data

Thirteen patients ($n = 13$) were treated with the simple rod rotation technique (SRR) and 17 with the DVD technique. The mean age at surgery for the SRR group was 14.8 ± 1.8 years and for the DVD group 14.5 ± 1.3 years ($p = 0.46$).

The mean follow-up in the SRR group was 32.2 ± 7.8 months and in the DVD group 30 ± 8 months ($p = 0.980$). All patients showed solid fusion on latest follow-up. The fusion in the SRR group comprised on average 7.7 segments (range 6–11) and in the DVD group 8.4 segments (range 6–11). An average of 1.3 pedicle screws per fused segment was used in the SRR group and 1.5 screws in the DVD group ($p > 0.1$).

Coronal plane

The main thoracic curve in the SRR group measured 62.3° ± 12.1° before surgery and in the DVD group 62.4° ± 12° ($p = 0.966$). Those were corrected to 21.4° ± 7.2° and 19.5° ± 5.8° corresponding to 67 and 69% of correction, respectively ($p = 0.375$). Preoperative and postoperative curve magnitude as well as correction between both groups showed no statistically significant difference ($p > 0.05$). Preoperative coronal balance (CB) in the SRR group was normal and remained within physiologic limits (±20 mm) in all 13 patients at the latest follow-up. CB in the DVD group was abnormal (>±20 mm) before surgery in 6 patients and improved to or remained within normal limits in all 17 patients at the latest follow-up.

Sagittal plane

Thoracic kyphosis before surgery was 13.9° ± 9.7° in the SRR group and 23.4° ± 9° in the DVD group. On the latest follow-up, TK in the SRR group measured 16.7° ± 8.3 showing a minimal increase of 2.8° ± 7.4° ($p = 0.193$). TK in the DVD group measured on the latest follow-up is 15.2° ± 6.9°, thus showing a significant decrease of 8.2° ± 6.3° ($p < 0.0001$).

Lumbar lordosis in the SRR group measured 45.1° ± 7.7° before surgery and remained unchanged at latest follow-up 45.3° ± 9.8° ($p = 0.918$) Lumbar lordosis in the DVD group measured 53° ± 11.3° before surgery and 41.2° ± 12.2° at the latest follow-up, showing a significant decrease of 11.8° ± 10.2° ($p < 0.0001$).

Sagittal balance in the SRR Group improved from 24.5 ± 16.9 mm before surgery to 16.3 ± 10.8 mm at the latest follow-up. SB in the DVD group improved from 30.5 ± 20.4 mm before surgery to 11.8 ± 8.4 mm at the latest follow-up.

The results are summarized in Table 1 and 2.

Discussion

The role of the sagittal alignment for the preservation of the normal posture and the structural health of the spine has been well recognized [8]. Although "flat back" syndrome applies to fusions extending to the lumbar spine, decrease

Table 1 Preoperative and postoperative values of both groups with statistical evaluation

	SRR	DVD	*p*
Age (years)	14.8 ± 1.8	14.5 ± 1.3	0.46
Follow-up (months)	32.5 ± 7.8	30 ± 8	0.98
Cobb AP pre op	62.3 ± 12.1°	62.4 ± 12°	0.966
Cobb AP latest f/u	21.4 ± 7.2	19.5 ± 5.8°	0.375
CB pre op (mm)	11.2 ± 5.5	17 ± 11	0.111
CB latest f/u (mm)	13 ± 6.1	8.2 ± 6.4	0.235
TK pre op	13.9 ± 9.7°	23.4° ± 9°	<0.0001
TK latest f/u	16.7 ± 8.3°	15.2° ± 6.9°	0.796
LL pre op	45.1° ± 7.7°	53° ± 11.3°	0.014
LL latest f/u	45.3° ± 9.8°	41.2 ± 12.2°	0.700
SB pre op (mm)	24.5 ± 16.9	30.5 ± 20.4	0.364
SB latest f/u (mm)	16.3 ± 10.8	11.8 ± 8.4	0.378
Number of screws per fused segment	1.3	1.5	>0.1

Table 2 Comparison between preoperative and postoperative TK and LL in both groups

	Before surgery	Latest f/u	Difference	*p*
TK SRR	13.2 ± 9.7°	16.7 ± 8.3°	+2.8° ± 7.4°	0.193
LL SRR	45.1° ± 7.7°	45.3° ± 9.8°	+0.2° ± 7.9°	0.918
TK DVD	23.4° ± 9°	15.2° ± 6.9°	−8.2° ± 6.3°	<0.0001
LL DVD	53° ± 11.3°	41.2 ± 12.2°	−11.8° ± 10.2	<0.0001

of lumbar lordosis as a result of thoracic hypokyphosis has recently been reported after selective posterior thoracic fusion [2]. The authors found that lumbar lordosis decreased significantly in patients with decreased thoracic kyphosis and emphasized the critical role of preserved thoracic kyphosis for preventing iatrogenic loss of lumbar lordosis. Given the fact that the thoracic sagittal profile in AIS is usually hypokyphotic, procedures with lordogenic effect, that further decrease thoracic kyphosis, should be avoided. Simple rod rotation with concave-sided distraction has been used as a correction maneuver for many years in posterior spinal surgery for AIS [3]. After the introduction of pedicle screw instrumentation, a better correction of coronal deformity was reported as compared to hook-only and hybrid constructs. However, all-pedicle screw constructs have been found to be more lordogenic [9–12].

Recently, a technique using DVD of the apical and the juxtaapical spinal segments has been described [6]. Significant improvement of the apical vertebral rotation has been reported with this technique as compared to single rod rotation (42 vs. 2%).

Dickson et al. [13, 14] hypothesized that the primary pathogenetic mechanism of scoliosis development is anterior spinal overgrowth with resulting thoracic hypokyphosis and lateral buckling of the spinal column. This theory was recently supported by Guo et al. [15]. Based on this, Hyashi et al. [7] anticipated that procedures associated with better correction of the apical vertebral rotation will further decrease thoracic hypokyphosis.

The results of our study demonstrate that thoracic kyphosis increased minimally by 2.8° in the SRR group and decreased in the DVD group by 8.1° ($p < 0.0001$). We found a significant hypokyphotic effect of DVD on the thoracic spine. However, the precise pathomechanism of the decreased thoracic hypokyphosis is still unclear, and it may be hypothesised that pushing the convex side of the spine in back to front direction when performing the derotational maneuver may lead to flattening of the thoracic spine. Lumbar lordosis remained unchanged in the SRR group and decreased significantly in the DVD group by 11.8° ($p < 0001$), confirming the hypolordotic effect of decreased TK on the unfused lumbar spine as described by Newton et al. [2]. Decreased lumbar lordosis is most probably a compensatory mechanism to preserve global sagittal alignment. What the effect of this loss in LL after a decrease in TK will have in the patient's long-term outcome is still unclear. The degenerative changes as a consequence of "flatback syndrome" are seen decades after the index procedure especially in cases that had their instrumentation extending into the lower lumbar spine. All our patients had their lower instrumented vertebra at L1 or above. However, because there is a loss of lordosis with aging, it is reasonable to use techniques that would minimize a decrease in LL (Fig. 1).

Potential limitation of the study is its retrospective design. Data for clinical correction of the rib hump were not available for all patients; thus, it was not possible to compare improvement of cosmetic appearance between both groups.

Another limitation is that TK and LL were evaluated on standard lateral X-rays and not on true lateral X-rays

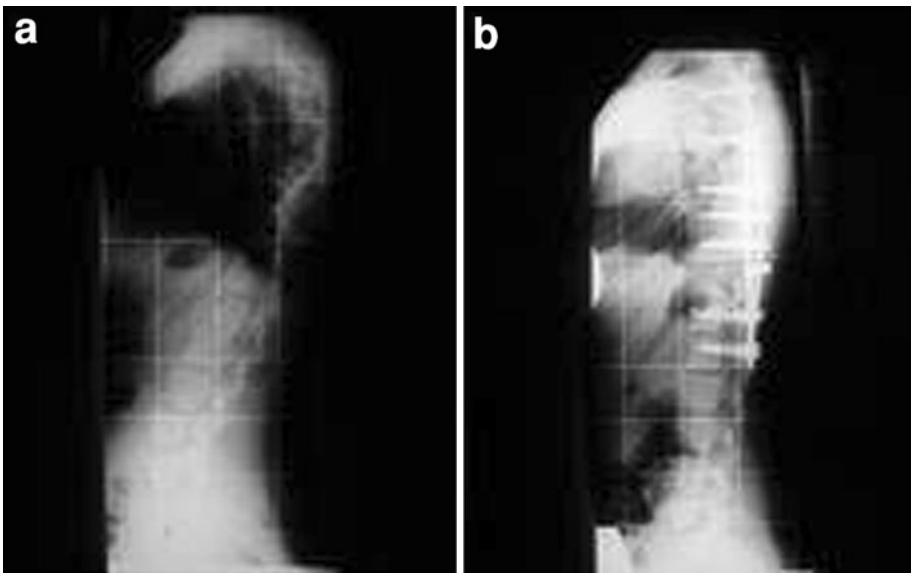

Fig. 1 Lateral standing X-ray of a 13-year-old female with AIS Lenke type 1a curve, showing preoperative thoracic kyphosis of 25° and lumbar lordosis of 40° (**a**). On latest follow-up (**b**) 3 years after posterior instrumentation using direct vertebral derotation and selective thoracic fusion, there was a significant flattening of thoracic kyphosis (10°) and decrease in the lumbar lordosis (20°). **a** ESJ DVD lat pre op. **b**. ESJ DVD lat post op

corrected for residual spinal rotation, which may be a source for possible projectional errors.

Conclusions

Decrease of thoracic kyphosis and lumbar lordosis can be encountered with better rotational correction of thoracic spinal deformity. In order to preserve harmonic thoracic kyphosis, lumbar lordosis and global sagittal alignment, the use of more rigid cobalt chrome rods or maneuvers that pull posteriorly the concave side of the spine, thus avoiding the application of additional flattening forces, should be discussed. However, the beneficial effects of these options remain to be studied.

References

1. Majdouline Y, Aubin CE, Robitaille M et al (2007) Scoliosis correction objectives in adolescent idiopathic scoliosis. J Pediatr Orthop 27:775–781
2. Newton PO, Yaszay B, Upasani VV, Pawelek JB, Bastrom TP, Lenke LG, Lowe T, Crawford A, Betz R, Lonner B, Group Harms Study (2010) Preservation of thoracic kyphosis is critical to maintain lumbar lordosis in the surgical treatment of adolescent idiopathic scoliosis. Spine 35(14):1365–1370
3. Cotrel Y, Dubousset J, Guillomat M (1988) New universal instrumentation in spinal surgery. Clin Orthop 227:10–23
4. Suk SI, Lee CK, Kim WJ et al (1995) Segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis. Spine 20:1399–1405
5. Bridwell KH (1994) Surgical treatment of adolescent idiopathic scoliosis: the basics and the controversies. Spine 19:1095–1100
6. Lee SM, Suk SI, Chung E-R (2004) Direct vertebral rotation: a new technique of three-dimensional deformity correction with segmental pedicle screw fixation in adolescent idiopathic scoliosis. Spine 29(3):343–349
7. Hayashi K, Upasani VV, Pawelek JB, Aubin C-E, Labelle H, Lenke LG, Jackson R, Newton PO (2009) Three-dimensional analysis of thoracic apical sagittal alignment in adolescent idiopathic scoliosis. Spine 34(8):792–797
8. La Grone MO (1988) Loss of lumbar lordosis. A complication of spinal fusion for scoliosis. Orthop Clin North Am 19:383–393
9. Lowenstein JE, Matsumoto H, Vitale MG et al (2007) Coronal and sagittal plane correction in adolescent idiopathic scoliosis: a comparison between all pedicle screw versus hybrid thoracic hook lumbar screw constructs. Spine 32:448–452
10. Kim YJ, Lenke LG, Kim J et al (2006) Comparative analysis of pedicle screw versus hybrid instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. Spine 31:291–298
11. Vora V, Crawford A, Babekhir N et al (2007) A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: myth or reality. Spine 32:1869–1874
12. Kim YJ, Lenke LG, Cho SK et al (2004) Comparative analysis of pedicle screw versus hook instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. Spine 29:2040–2048
13. Dickson RA, Lawton JO, Archer IA et al (1984) The pathogenesis of idiopathic scoliosis. Bi-planar spinal asymmetry. J Bone Joint Surg [Br] 66:8–15
14. Dickson RA (1992) The etiology and pathogenesis of idiopathic scoliosis. Acta Orthop Belg 58(suppl):21–25
15. Guo X, Chaw WW, Chan YL et al (2003) Relative anterior spinal overgrowth in adolescent idiopathic scoliosis. Results of disproportionate endochondral membranous bone growth. J Bone Joint Surg [Br] 85:1026–1031