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Dorsal instrumentation for idiopathic adolescent thoracic scoliosis: rod rotation versus translation

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Abstract The radiographic and clinical outcomes and complications among two groups of adolescent patients treated for idiopathic thoracic scoliosis with dorsal instrumentation using a unified implantation system (Universal Spinal System) were compared retrospectively. A total of 69 patients were included in the study. In 30 patients an intraoperative correction of the scoliosis was performed by translation and segmental correction (translation group, Helsinki). In 39 patients the correction was achieved according to the Cotrel-Dubousset rod rotation maneuver (rod rotation group, Berlin). The goal of the present study is to investigate whether one of the operative procedures leads to a better correction of idiopathic adolescent thoracic scoliosis than the other. The mean follow-up interval was 30 months, with a minimum of 12 months. There were no significant preoperative differences in age (15 ± 2 years in both groups), gender, or type of scoliosis (King types 2, 3, and 4). The preoperative radiographic measurements showed no significant differences between the

two groups. In both patient groups, the thoracic primary curve, the lumbar secondary curve and the thoracic apical rotation were improved by the operation. Lumbar apical rotation and the sagittal profile were unchanged in both groups. The thoracic primary curve was corrected from $50^\circ \pm 6^\circ$ to $24^\circ \pm 7^\circ$ in the translation group and from $54^\circ \pm 11^\circ$ to $22^\circ \pm 11^\circ$ in the rod rotation group. The extent of the correction of the thoracic curve was significantly greater in the rod rotation group than in the translation group (59% vs 52% correction). In contrast, the translation procedure seems to have a more beneficial effect on spinal balance than rod rotation. Neurological complications did not occur. In both patient groups an increase in the non-instrumented lumbar curve was noted, in two cases each. In three patients from the rod rotation group the instrumentation had to be removed due to a late infection with negative microbiological results.

Key words Idiopathic scoliosis · Dorsal spondylodesis · Surgical technique

Introduction

The operative technique introduced by Cotrel and Dubousset (CD) attempts to achieve an improvement of the sagittal profile and a derotation of the vertebrae, in addition to a correction of the main curvature of the scoliotic

spine, by rotation of the concave-side rod [6, 21]. Even though a derotating effect has not been convincingly demonstrated [20, 22], the rod rotation procedure has found increasing acceptance and use.

The technique of segmental correction was described by Luque [17]. The correction of the scoliosis is performed after fixation of vertebrae with sublaminar wires,

followed by segmental correction of the deformed spine. In the beginning of the 1990s the Universal Spinal System (USS) was introduced [14, 24] and an operating technique was developed to avoid spinal decompensation and to take advantage of the principle of segmental correction of scoliosis (translation technique). In addition to the correction of the major and minor curvature, a segmental correction of vertebral rotation and improvement of the sagittal profile of the spine may be achieved with this technique. The goal of the present study is to investigate whether one of the two operative procedures (rod rotation vs translation maneuver) leads to a better correction of idiopathic adolescent thoracic scoliosis than the other.

Materials and methods

Patients with adolescent idiopathic thoracic scoliosis have been treated with the USS using a translation procedure since 1992 at the Orthopedic Hospital of the Invalid Foundation in Helsinki. The USS was introduced in 1994 in the Charité Hospital of the Humboldt-University Berlin; however, the surgical procedure for operative correction of the scoliosis was performed analogously to the rod rotation procedure of Cotrel and Dubousset. For the present study, clinical records for all 212 patients treated for scoliosis using the USS in either center were reviewed. All patients with idiopathic thoracic scoliosis of King types 2, 3, or 4 [10] were entered into the study. Patients with non-idiopathic scoliosis or with systemic disorders such as Marfan syndrome or neurofibromatosis were excluded, as were patients who were operated upon less than 6 months prior to the study. Patients who were treated with a ventral operation prior to dorsal instrumentation (ventral liberation or VDS according to Zielke) or patients who received a thoracoplasty were also excluded. Of the remaining 69 patients, 39 were treated in Berlin using rod rotation, and 30 were treated in Helsinki with the translation procedure.

Fig. 1 Schematic illustration of (left) the CD maneuver (rod rotation followed by distraction), and (right) the translation maneuver (segmental correction by dorsal and transverse traction on the pedicle hooks)

All operations were performed by M.M. or D.S. Only USS stainless steel implants were used. The patients were placed in a prone position on a Relton Hall frame. In the rod rotation procedure (Figs. 1, 2), the hooks were placed on the concave side of the cranial and caudal end vertebrae as well as cranial and caudal to the apex of the curve. Both cranial hooks were pedicle hooks, whereas both caudal hooks were sublaminar hooks. On the convex side, two hooks were positioned on the cranial terminal vertebra as a claw grip; also, hooks were placed at the apex of the curve and on the caudal terminal vertebra. In later operations, both hooks at the caudal terminal vertebra were replaced by pedicle screws (altogether 62 patients with screws, 7 patients with hooks). Following opening of the facets and decortication of the laminae, a slightly bent rod was positioned on the concave side and rotated by 90° from the frontal to the sagittal plane. Additionally, distraction between the hooks was performed to improve the correction (Fig. 1). After convex rod insertion and insertion of transverse stabilizers, bone strips from corticospinospongiosa of the posterior iliac wing were applied for spondylodesis.

In contrast to the rod rotation procedure, for the translation procedure (Figs. 1, 3) the fixation of the rod on the concave side is performed in the final position of the caudal terminal vertebra, i.e., the curvature of the rod corresponds to the thoracic kyphosis. On the concave side of the curve pedicle hooks were positioned according to the situation. Generally, every second vertebra was instrumented with a pedicle hook. With a special repositioning device the hooks on the concave side (and with them the corresponding vertebrae) were pulled up the rod by dorsal and transverse traction. Segmental derotation was thus attempted in addition to the correction of the main curve. After placement of the convex rod and insertion of transverse stabilizers, autogenic bone strips were also applied for spondylodesis. In both patient groups perioperative antibiotics were given. The patients were mobilized without corset, starting on the 2nd postoperative day. Clinical and radiographic follow-up examinations were performed 3, 6, 12, and 24 months after the operation.

The evaluation of the patient records and radiographic measurements were performed by an independent observer (C.K.). From the posteroanterior view, the Cobb angles of the primary and secondary curves were measured, and the rotation of the apex vertebra of the primary and secondary curves was measured according to Perdriolle [19]. Spinal balance was measured as the perpendicular distance of the spinal process of the seventh cervical vertebra from the central sacral line. The spine was considered to be balanced if this distance was less than 10 mm to the left or to the right (−10 mm to +10 mm). From the lateral radiographs of the vertebral column, thoracic kyphosis from T4 to T12 and lumbar lordosis from L1 to L5 were measured. All measurements were performed preoperatively and on follow-up radiological examinations. The evaluation of complications was performed using patient records (hospital and office charts). For statistical analysis, calculations were processed using the statistics program SPSS (SPSS Inc., Chicago, Ill.) version 4.0 software.

Results

The age distribution of the patients at the time of operation, as well as gender, follow-up time, and scoliosis type according to the King classification, showed no significant differences between the translation and rod rotation groups (Table 1). The follow-up period for the translation group was to 32 ± 5 months (range 12–42 months), and 28 ± 6 months in the rod rotation group (range 12–36 months).

Fig. 2 A, B Idiopathic adolescent scoliosis and instrumentation with the Universal Spinal System: rod rotation technique. Posteroanterior radiographs before (A) and 28 months after (B) the operation

Fig. 3 A, B Idiopathic adolescent scoliosis and instrumentation with the Universal Spinal System: segmental correction technique. Posteroanterior radiographs before (A) and 32 months after (B) the operation

The analysis of the measurements of the thoracic primary and the lumbar secondary curves, as well as of the thoracic kyphosis and lumbar lordosis, is presented in Table 2. A direct comparison of both patient groups showed no significant difference in these parameters either preoperatively or at follow-up. In both patient groups an improvement in the primary and secondary curves as well as in the apical rotation of the primary thoracic curve was achieved. In contrast, neither the apical rotation of the lumbar curve nor the sagittal profile of the vertebral column was significantly improved by the operation.

There was a difference between the two patient groups in the extent of correction of the thoracic primary curve (expressed as difference between preoperative and follow-up measurements), as seen in Table 3. The rod rotation procedure achieved a significantly better correction: 59% versus 52% in the translation group. There were no significant differences between the two groups in correction of the lumbar secondary curve, of the thoracic or lumbar apical rotation, or of the sagittal profile.

Fig. 4 A, B Clinical picture of a 15-year-old girl with idiopathic thoracic scoliosis (Fig. 2) before (A) and 12 months after (B) the operation with an improvement of shoulder balance

The influence of the two operation techniques on spinal balance is presented in Table 4. Both techniques seemed to be able to improve the spinal balance in patients with scoliosis with an imbalance to the right. For these patients, the

Table 1 Comparison of the two groups by patient age, sex, and type of scoliosis according to King classification

	Rod rotation group	Translation group
Mean age (range)	15 ± 2 (10–18) years	15 ± 2 (10–20) years
Gender	33 girls 6 boys	27 girls 3 boys
King type 2	18	11
King type 3	15	15
King type 4	6	4

number of imbalanced vertebral columns was reduced from 13 to 5 in the rod rotation group and from 12 to 4 in the translation group. The rod rotation method seemed to increase the number of vertebral columns with imbalance to

the left (preoperative: 14; postoperative, 22); the number of spines with imbalance to the left was reduced in the translation group from 17 to 16. The total percentage of balanced spines on follow-up was thus increased in the translation group (preoperative 3% vs 33% on follow-up), but unchanged in the rod rotation group (preoperatively and at follow-up 31%). The translation procedure had a more beneficial influence for the overall balance of the spine.

The number of vertebral bodies included in the instrumentation was different for both groups (Table 5). In the rod rotation group, 10 ± 1 vertebral bodies (range 7–12) were fused, and in the translation group 11 ± 1 (range 8–14). The difference in the length of the fused segment was statistically significant ($P = 0.049$).

The complications that occurred are summarized in Table 6. No neurological complications were noted in ei-

Table 2 Comparison of preoperative and follow-up measurements shows no significant differences in any of the parameters between the rod rotation group and the translation group (all measurements expressed in degrees with mean and standard deviation, and minimum and maximum values in parentheses)

	Rod rotation group	Translation group	Significance
<i>Preoperative</i>			
Thoracic major curvature	54 ± 11 (36:74)	50 ± 6 (42:65)	$P = 0.11$ (n.s.)
Lumbar secondary curvature	29 ± 9 (11:56)	27 ± 7 (13:41)	$P = 0.50$ (n.s.)
Thoracic rotation (apex)	21 ± 9 (5:35)	19 ± 9 (5:35)	$P = 0.61$ (n.s.)
Lumbar rotation (apex)	8 ± 7 (0:30)	9 ± 5 (0:20)	$P = 0.61$ (n.s.)
Thoracic kyphosis (T4–12)	19 ± 10 (2:43)	23 ± 12 (8:46)	$P = 0.22$ (n.s.)
Lumbar lordosis (L1–5)	22 ± 9 (10:40)	24 ± 8 (5:38)	$P = 0.28$ (n.s.)
<i>Follow-up</i>			
Thoracic major curvature	22 ± 11 (10:56)*	24 ± 7 (11:37)*	$P = 0.08$ (n.s.)
Lumbar secondary curvature	14 ± 8 (3:34)*	15 ± 8 (4:34)*	$P = 0.64$ (n.s.)
Thoracic rotation (apex)	16 ± 10 (0:35)*	17 ± 7 (5:30)**	$P = 0.56$ (n.s.)
Lumbar rotation (apex)	8 ± 8 (0:30)***	10 ± 6 (5:25)***	$P = 0.56$ (n.s.)
Thoracic kyphosis (T4–12)	22 ± 9 (5:40)***	19 ± 7 (7:33)***	$P = 0.30$ (n.s.)
Lumbar lordosis (L1–5)	20 ± 8 (9:40)***	21 ± 7 (5:35)***	$P = 0.45$ (n.s.)

* $P < 0.01$; ** $P < 0.05$; *** n.s. (all compared with preoperative values)

Table 3 Comparison of the correction (difference between preoperative and follow-up values) for the measured parameters of the rod rotation group and the translation group (expressed in degrees with mean and standard deviation, and minimum and maximum values in parentheses)

	Correction		Significance
	Rod rotation group	Translation group	
Thoracic major curvature	32 ± 12 (6:51)	25 ± 7 (11:39)	$P = 0.0093$
Lumbar secondary curvature	15 ± 8 (–2:33)	12 ± 7 (–3:25)	$P = 0.12$ (n.s.)
Thoracic rotation (apex)	5 ± 8 (–10:20)	2 ± 5 (–5:10)	$P = 0.17$ (n.s.)
Lumbar rotation (apex)	1 ± 4 (–10:15)	–1 ± 4 (–10:5)	$P = 0.13$ (n.s.)
Thoracic kyphosis (T4–12)	0 ± 9 (–16:23)	3 ± 8 (–18:20)	$P = 0.12$ (n.s.)
Lumbar lordosis (L1–5)	3 ± 9 (–20:21)	2 ± 8 (–11:14)	$P = 0.76$ (n.s.)

Table 4 Number (percentage) of patients with balanced spines (distance between central sacral line and a vertical line drawn from the spinal process of C7 < 10 mm) and of patients with spines im-

balanced to the right or to the left (distance > 10 mm) preoperatively and at follow-up for the rod rotation group and the translation group

	Rod rotation group			Translation group		
	Balanced	Imbalanced to left	Imbalanced to right	Balanced	Imbalanced to left	Imbalanced to right
Preoperative	12 (31%)	14 (36%)	13 (33%)	1 (3%)	17 (57%)	12 (40%)
Follow-up	12 (31%)	22 (56%)	5 (13%)	10 (33%)	16 (54%)	4 (13%)

Table 5 Number (percentage) of vertebral bodies fused by spondylodesis for the rod rotation and translation groups

No. of vertebrae fused	No. of patients (%)	
	Rod rotation group	Translation group
7	1 (3%)	
8	3 (8%)	1 (3%)
9	13 (33%)	5 (17%)
10	7 (18%)	8 (27%)
11	9 (23%)	8 (27%)
12	6 (15%)	5 (17%)
13		2 (7%)
14		1 (3%)

Table 6 Number of complications in each group

Complication	Rod rotation group	Translation group
Intraoperative pull out of a screw	0	2
Breakage of rod/screw	1 ^a	0
Dislocation of a hook	1	1 ^a
Lumbar decompensation	2 ^a	1 ^a 1 ^b
Late deep infection and removal of the hardware	3 ^a	0
Cast syndrome	1	0

^a Reoperation performed^b Operative correction not necessary

ther group. Three late infections occurred in the rod rotation group 12, 15, and 18 months postoperatively. Pre- and intraoperative microbiological investigations were negative. After total removal of metal instrumentation with stable spondylodesis, the wounds healed without further complications. One case of cast syndrome was successfully treated conservatively. In four patients there was an increase in the non-instrumented lumbar curvature; in three of these cases a caudal extension of the spondylodesis was necessary.

Discussion

Various techniques have been employed in the operative correction of scoliosis: distraction, compression, segmental correction, and rod rotation. The usefulness of the CD maneuver for correction of the thoracic major and minor curvature has been well documented. Various studies have reported an improvement of between 45% and 70% in the original curvature [2, 11, 20, 21]. The evaluation of our patients revealed an average correction of 32° (corresponding to 59% of the original curvature of on average 54°).

In contrast, the ability of the CD maneuver to correct the rotation and sagittal profile of the scoliotic vertebral

column remains controversial. Schlenszka et al. demonstrated no significant improvement of the thoracic rotation in 52 patients in their CD group, when measured using the method of Perdriolle [20]. Krismmer et al. and Lenke et al. also failed to document a rotation correction using CT [11, 15]. However, other workers have shown a derotation of between 20% and 40% using radiographic or CT measurements [7, 8, 19]. The results of our study underline the potential of the CD maneuver to create a lasting derotation of the thoracic rotation. In our view, the statistically significant derotation was made possible by the use of pedicle screws at the caudal end of the instrumentation [23]. Presumably, since these pedicle screws are nearer to the rotational center than lamina hooks, which attach more dorsally, they are able to exert more force. On the other hand, the Perdriolle method is characterized by a lack of precision, especially in combination with pedicle hooks or screws which may cover the pedicles that need to be measured.

Correspondingly, our measurements of lumbar rotation should be viewed critically. We did not show any difference in comparison to the preoperative measurements. In the literature one finds only a few, mainly controversial, reports concerning the influence of the CD maneuver on lumbar rotation. Published studies have shown a correction [7, 8], no difference [12], and even a worsening of lumbar rotation [7, 20].

The thoracic and lumbar sagittal profile was not measurably influenced in either of the two treatment groups. According to Bridwell et al., normal thoracic kyphosis measures between 20° and 40° [3]. Our patients showed a normal average preoperative and follow-up thoracic kyphosis. In light of the small patient numbers in the two groups, we did not perform a further subclassification into patients with initial hypokyphotic and normokyphotic initial thoracic spines. In the literature one finds, as is the case with thoracic rotation, differing results. Lenke et al. reported an improvement of the initial kyphotic angle from 18° to 25°; however, other authors reported no significant influence on the sagittal profile [2, 8, 11, 12, 16, 20, 22]. In many cases, including the present study, two basic problems were not addressed in the measurement of thoracic kyphosis in patients with idiopathic scoliosis. Firstly, the kyphosis was always measured between T4 and T12. This did not take into consideration the fact that idiopathic scoliosis is often associated with lordosis at the apex of the curvature. Global measurements comprising T4 to T12 may tend to overlook these differences. Secondly, due to the intraoperative derotation, the pre- and postoperative lateral radiographs may not be directly comparable. For such cases, "true lateral" radiographs may be necessary, with oblique exposures that correspond to the actual apical rotation.

The results of our study for the rod rotation group are comparable with the results presented in the literature. It is generally agreed that it is possible to achieve a good

correction of the major and minor curvature with the CD method, whereas there is a lesser influence on rotation and sagittal profile. Balance problems related to the CD procedure have been described. Cases of scoliosis with a preoperative deviation from the midline (vertical line from C7 to S1) show an especially high risk of developing balance problems, as do those cases in which the instrumentation was only performed up to the "stable" vertebral body [4]. In the translation group, the spondylodesis was one vertebra longer than in the rotation group. This fact, as well as the less forced correction of the major curvature, could explain the tendentially better postoperative balance in this patient group.

Among our two patient groups, the rod rotation group showed a significantly higher degree of correction of the thoracic major curvature (59% vs 52%). In our view, it is possible to apply greater force on the scoliotic spine by using sublaminar hooks near the apex of the curvature on the concave side. In support of this hypothesis, we would like to mention that we have observed that the bent rod may bend back during the rod rotation maneuver. With the translation procedure, this did not occur. Also, the pedicle hook is more laterally positioned and nearer to the rod, which may lead to less correction. The larger degree of correction seen for the rod rotation group may possibly be related to the stronger distraction of the spine and to the shorter length of scoliosis instrumentation.

The correction of the lumbar minor curvature and of the thoracic rotation did not show significant differences between the two groups. Lumbar rotation and the sagittal profile were not influenced significantly by either of the two operative techniques. To our knowledge, Labelle et al. have published the only report to date on the translation technique [13]. They demonstrated no significant differences between the translation and rod rotation techniques using a computer-assisted digital measuring system. The correction of the thoracic curvature was reported as 57%, which corresponds to our results. In contrast, Labelle et al. achieved a correction of the lumbar minor curvature of 65%, which was clearly more than in our study. To our knowledge, however, Labelle et al. use a broader indication than we do for performing instrumentation of the lumbar minor curvature, so that a stronger correction of this parameter is to be expected. They also indicate an improvement in the thoracic kyphosis and lumbar lordosis of 40% and 42%, respectively, whereas we did not show an influence on the sagittal profile.

The segmental correction of the scoliotic spine was first described by Luque. The application of sublaminar wire cerclages is, however, associated with significant neurological risks, which has limited the use of this technique [5]. The polysegmental fixation of the spine using pedicle hooks follows the principle of segmental correc-

tion. Analysis of our group of 30 patients operated on with this method shows an improvement of the thoracic major and the lumbar minor curvature to about half of the original curvature. The rotation in the apical curvature could also be reduced.

McMaster reported a good scoliosis correction in the frontal and sagittal profiles in a series of 152 patients using Luque instrumentation, but did not demonstrate a significant derotation of the apical segment [18]. In Hullin et al.'s analysis of 40 cases of thoracic scoliosis operated on using Luque instrumentation, only 6 patients showed a reduction of the rib hump, in 27 patients there was no change and 7 patients showed an exacerbation of the rib hump [9].

Finally, it should be mentioned that the translation procedure is a new technique with new corrective elements compared to the CD maneuver [1]. The technical skill and expertise of the surgeons with the CD maneuver might have been advantageous to the rod rotation group.

However, the rate of complications is higher in the rod rotation group. In three cases, late infection led to the removal of the infected material. Interestingly, in all three cases, no bacterial growth was observed in cultures [20]. The clinical picture of late infection may possibly have reflected a reaction to the metal in these patients. Histological examination of tissue located next to the implant showed a high proportion of eosinophilic granulocytes in one patient. An increase in the non-instrumented lumbar curvature necessitated an extension of the spondylodesis in two patients in the rod rotation group and one patient in the translation group. In one case we saw a cast syndrome, which was treated conservatively. The increase in height of the girl with the cast syndrome was 6 cm.

Conclusion

Based on the results of this non-prospective, non-randomized study with a small number of patients, the ability of the translation technique to correct the thoracic major curvature seems to be less than that of the rod rotation system. No differences are to be expected in the correction of the lumbar minor curvature or of the rotation of the thoracic apex. Neither procedure is expected to influence the sagittal profile or lumbar rotation. The risk of decompensation of the non-instrumented lumbar curvature appears to be equal for both procedures. In contrast, the translation technique seems to have a more beneficial influence on the balance of the scoliotic spine than the rod rotation procedure. Further studies will be needed to determine whether these differences between the two operative techniques are clinically relevant, and which of the techniques is most advantageous.

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