Anterior Instrumentation for Correction of Adolescent Thoracic Idiopathic Scoliosis: Historic Prospective Study

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Aim To compare the results of anterior instrumentation and standard posterior procedure for correction of adolescent thoracic idiopathic scoliosis.

Methods The study included 50 patients with adolescent thoracic idiopathic scoliosis who underwent corrective spinal surgery. Anterior spinal fusion by use of modified Zielke ventral derotation system (anterior approach to spine through thorax) was performed in 25 patients, whereas posterior approach was used in 25 patients. The average preoperative thoracic curve in coronal plane was 66.7 ± 9.9° and 65.0 ± 11.7° in the anterior and posterior correction groups, respectively. The median age of patients before surgery was 14 years (range, 12-18) in the anterior and 16 years (range, 13-18) in the posterior correction group. Women-to-men ratio was 22 to 3 in each group. Coronal and sagittal correction, apical vertebral body rotation, rib hump, and rib depression correction were measured before surgery and at the first (30 days after surgery) and at the second follow-up visit (at least 2 years after surgery). Posteroanterior and laterolateral radiographs of the erect spine were used (according to the method of Cobb and Nash-Moe) to assess coronal, sagittal, and horizontal plane corrections. Rib hump and rib depression were measured with Thulbourne-Gillespie measuring device. The differences in scoliosis correction parameters in the two groups were tested with Student two-tailed *t* test.

Results In the coronal plane, the thoracic curve of 66.7 ± 9.9° before surgery in the anterior correction group was reduced to 14.8 ± 8.7° after surgery (78.1 ± 12.4% relative correction), and the curve of 65.0 ± 11.7° in the posterior correction group was corrected to 29.2 ± 7.8° after surgery (55.1 ± 8.6% relative correction) (P<0.001). Apical vertebral body rotation correction according to the Nash-Moe classification from 2.0 ± 0.4° to 0.8 ± 0.6° was achieved in the anterior correction group (62.0 ± 26.6% relative correction) and from 1.7 ± 0.5° to 1.4 ± 0.5° in the posterior correction group (12.0 ± 21.8% relative correction) (P<0.001). Rib hump correction from 22.4 ± 15.5 mm to 5.4 ± 5.2 mm was found in the anterior correction group (70.9 ± 26.0% relative correction) and from 25.3 ± 7.0 mm to 13.6 ± 6.8 mm (48.4 ± 16.5% relative correction) in the posterior correction group (P = 0.084).

Conclusion Compared with the standard posterior approach, the anterior approach resulted in better three-dimensional correction of idiopathic thoracic scoliosis.

In patients with adolescent idiopathic scoliosis, the spine is curved to the side and rotated around the long axis, producing unilateral prominence of the trunk. The prominence of the rib cage is visible on the convex side of the curve and depression is present on the concave side. It is often the rib hump rather than the lateral curve that is the major cosmetic deformity (1). The prevalence of idiopathic scoliosis varies significantly because of the lack of uniformity in defining target population and the use of different definitions of scoliosis (2,3).

Traditionally, thoracic idiopathic scoliosis has been treated by posterior instrumentation and fusion, which is still the gold standard (4). Harrington instrumentation was the first accepted implant used for the correction of scoliosis (5). The next major step in scoliosis surgery was the use of Luque rods with sublaminar wires (6). Posterior spinal fusion with multisegmented hook-rod systems was widely used in the mid to late 1980s, with successful results (7). Suk et al (8) reported extensively on the posterior use of pedicle screw fixation for thoracic scoliosis, which also produced excellent results. Anterior spinal fusion with Dwyer instrumentation represented the first generation of anterior implants for correction of lumbar scoliosis (9). Subsequent to that, Zielke rigid rod anterior instrumentation has been adapted and used to save fusion levels in the distal lumbar spine (10). Because of the problems with a high rate of rod breakage reported during the follow-up study of Zielke instrumentation (11) used anteriorly for thoracic, thoracolumbar, and lumbar curves, a new rod-screw-nut system was developed. Slot added another rod to Zielke's instrumentation to correct kyphosis (12). The Harms Study Group elaborated and refined the concepts of anterior instrumentation for thoracic idiopathic scoliosis (13).

The posterior approach has a long history of success with different instrumentations, allowing a solution for any combination of thoracic deformities, whereas the anterior approach offers no possibility of correction for partial or complete structural left high thoracic curve (4). However, correction of the rotational component of thoracic spine deformity is not affected significantly with posterior approach (14,15). Kovač et al (16) showed better thoracic volume correction after the anterior than after the posterior approach. In some cases, a significant number of distal vertebral segments can be saved by use of anterior instrumentation, with an excellent spontaneous lumbar curve correction (17).

Controversy still exists about the benefits of the anterior in comparison with the posterior approach (4). The aim of this study was to compare the scoliosis correction after the anterior instrumentation with that obtained by the standard posterior procedure in patients with adolescent thoracic idiopathic scoliosis.

Patients and methods

Patients

The study included patients with adolescent thoracic idiopathic scoliosis who underwent either anterior or posterior spinal fusion for scoliosis correction between 1984 and 1998. The inclusion criteria were right adolescent thoracic idiopathic scoliosis according to the Scoliosis Research Society classification (18), at least 50° Cobb angle in the coronal plane, a minimum follow-up period of 2 years, and availability of clinical and radiographic data. Data of 72 patients treated in the study period were assessed during 2000 and 50 met the inclusion criteria. There were 25 patients who had undergone anterior spinal fusion (anterior correction group) with modified Zielke ventral derotation system (19) and 25 who were treated with the standard posterior spinal fusion procedure (posterior correction group) (20,21). All patients were surgically treated either at the Zagreb University Hospital Center or at Dubrava University Hospital, by one of the investigators (VK).

Table 1. Characteristics of the patients with idiopathic adolescent thoracic scoliosis before corrective spinal surgery

	Corrective surgery approach		
Characteristic	anterior	posterior	P*
Age (y)	14 (12-18)	16 (13-18)	0.063
Women/men ratio (No. of patients)	22/3	22/3	–
Follow up (mean±SD, mo)	47.9 ± 9.9	102 ± 68.4	<0.001
Coronal plane (mean±SD, Cobb angle)	66.7 ± 9.9°	65.0 ± 11.7°	0.576
Sagittal plane (mean±SD, Cobb angle)	23.5 ± 8.3°	24.5 ± 6.0°	0.658
Horizontal plane (mean±SD)†	2.0 ± 0.4	1.7 ± 0.5	0.014
Rib hump (mean±SD, mm)	22.4 ± 15.8	25.3 ± 7.0	0.394
Rib depression (mean±SD, mm)	21.2 ± 11.7	20.5 ± 7.0	0.804

*Student two-tailed *t*-test.
†Nash-Moe classification (24). SD, standard deviation.

The two patient groups did not differ in age and sex distribution or the measured parameters before the surgery (Table 1), except that the follow-up was significantly longer in the posterior correction group and the rotation of the apical vertebra (horizontal plane) according to the Nash-Moe classification (22) was significantly more pronounced in the anterior correction group.

Surgical technique

Anterior spinal fusion. The patient was placed in lateral decubitus position. A single skin incision was made over the 7th rib (for the instrumentation from T4 to T12) and the rib was removed. Complete disc and end plate material removal was essential. A vertebral body diameter was measured for screw length. Three rib osteotomies were usually performed across the deformity apex before the correction of the curve. Screws were placed transversely, with the tip of the screw being palpable on the concave side of the vertebral body. A threaded rod was then measured and two opposing nuts for each screw were put on the rod. The nuts were tightened sequentially, beginning at the cranial point of the curve, effecting a correction of the curve by shortening across the convexity. After the correction of the deformity, the second rod was added for stability of the instrumentation (19).

Posterior spinal fusion. The standard systems and techniques were used, as reported in the literature (20,21).

Outcome measures

Cobb angles in the coronal and sagittal planes and apical vertebral body rotation corrections (horizontal plane) were measured on the posteroanterior and laterolateral radiographs of the erect spine by the method of Cobb (23) and Nash-Moe classification (22). Rib hump and rib depression corrections were measured with Thulbourne-Gillespie measuring device (24). The measurements were carried out before surgery, 30 days after the surgery (the first follow-up visit), and at least 2 years after the surgery (the second follow-up visit). The minimum follow-up time after surgery was 24 months. Duration of surgery, bleeding during surgery, distal level of fusion, and duration of hospitalization after the surgery were also analyzed.

Statistical analysis

Data were presented as mean values with standard deviations (±SD). Student *t*-test with two-tailed significance was used for comparison of the two groups of patients before the corrective spinal surgery, and to test the differences between the mean corrections in the two groups after surgery. Two-tailed *t* test was also used to test the significance of correlations. The level of statistical significance was set at $P<0.05$. Statistical analysis was performed with SPSS for Windows, version 13 (SPSS Inc., Chicago, IL, USA).

Results

Anterior correction group

In the anterior correction group, the Cobb angle of the thoracic curve was 14.8 ± 8.7° in the coronal plane and 29.9 ± 5.3° in sagittal plane at the first follow-up visit (Figure 1). The deformity of the thoracic curve in the horizontal plane was corrected to 0.8 ± 0.6° at the first follow-up visit. The rib hump was reduced to 5.4 ± 5.2 mm and the rib depression to 7.7 ± 4.4 mm at the first follow-up visit. Higher values of Cobb angle in the

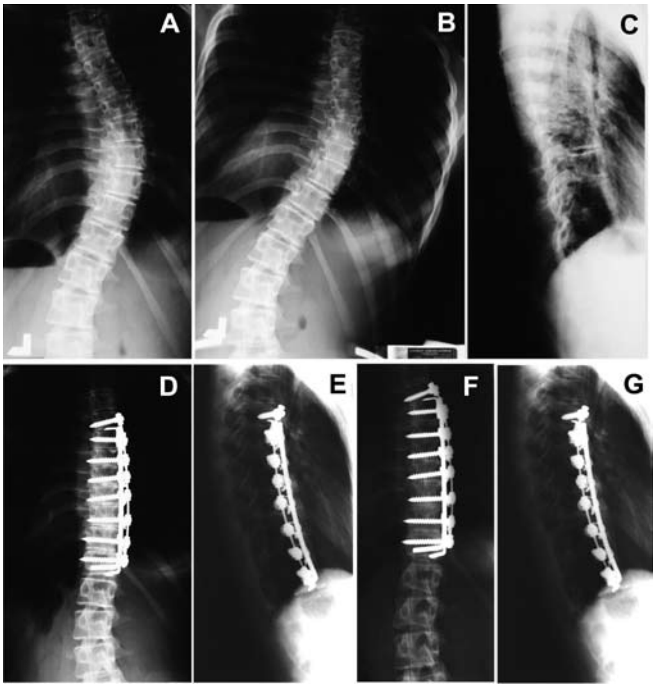

Figure 1. A 14-year-old girl with a right thoracic curve. The measurements on posteroanterior and laterolateral radiographs of the erect spine were carried out before surgery, 30 days after the surgery and at least 2 years after the surgery. **A.** Preoperative posteroanterior radiograph (Cobb angle of 56°). **B.** Right side bending radiograph evaluate flexibility of thoracic curve (Cobb angle of 36°). **C.** The lateral view demonstrates hypokyphosis (Cobb angle of 12°). **D.** First postoperative erect posteroanterior radiograph (30-day after surgery) showed excellent correction in frontal plane (Cobb angle of 4°). **E.** On first postoperative lateral radiograph balance in sagittal plane was restore (Cobb angle 22°). **F.** Posteroanterior radiograph obtained 2 years after surgery, showed minimal lost of correction for 2° (Cobb angle of 6°). G. Lateral radiograph obtained 2 years after surgery, showed no difference in sagittal plane (Cobb angle of 22°).

coronal plane, rib hump, and rib depression before surgery resulted in better absolute correction of these values after surgery.

Posterior correction group

In the posterior correction group, Cobb angles of the thoracic curve in the coronal and sagittal planes were 29.2±7.8° and 24.0±5.3°, respectively, at the first follow-up visit. The deformity in the horizontal plane was reduced to 1.4±0.5°, the rib hump was reduced to 13.6±6.8 mm, and the rib depression to 8.9±5.2 mm on the first follow-up visit. Higher values of Cobb angle in the coronal plane and rib depression before surgery resulted in better absolute correction of these values after surgery.

Comparison of postoperative findings in anterior and posterior group

Absolute correction of the thoracic scoliosis in the coronal plane was significantly larger after the anterior correction than after the posterior correction at both visits ($P<0.001$; Table 2). The correction loss between the first and the second follow-up visit was 4.0±4.4° in the anterior correction group and 5.4±9.1° in the posterior correction group. A mild kyphotic effect after the anterior correction visible in the sagittal plane was significantly more pronounced than that after the posterior correction at both visits (Table 2). The absolute correction in the horizontal plane after the anterior correction was significantly larger than that achieved after the posterior correction ($P<0.001$; Table 2). Between the first and the second follow-up visit, there was a minimal or non-existent correction loss in the horizontal plane in both groups (Table 2). The absolute correction of the rib hump achieved after the anterior correction was almost the same at the first and second visits (correction loss of 0.8±4.0 mm), whereas it decreased by 2.7±1.9 mm after the posterior correction. The rib hump correction at the second visit was significantly better after the anterior than after the posterior correction ($P=0.012$). The correction loss for

Table 2. Degree of coronal and sagittal correction, apical vertebral body rotation, and rib hump and rib depression corrections in patients with idiopathic thoracic scoliosis after anterior and posterior correction at the first and the second follow-up visit*

	Surgical correction (mean±SD)		
Aspect	anterior approach	posterior approach	P†
Coronal plane			
1st visit	51.9±10.5	35.8±8.2	<0.001
2nd visit	47.9±9.8	30.4±10.7	<0.001
Sagittal plane			
1st visit	5.2±6.0	1.0±3.8	<0.001
2nd visit	6.3±6.0	1.1±4.1	0.002
Horizontal plane			
1st visit	1.2±0.5	0.2±0.4	<0.001
2nd visit	1.2±0.5	0.2±0.6	<0.001
Rib hump			
1st visit	17.0±14.6	11.7±3.7	0.084
2nd visit	17.0±15.0	9.0±3.5	0.012
Rib depression			
1st visit	13.9±11.8	11.6±4.5	0.378
2nd visit	13.7±11.4	10.5±4.6	0.200

*The values present the difference from the baseline values before surgery.
†Two tailed *t* test.

the rib depression was 0.1 ± 3.0 mm between the first and second follow-up visit in the anterior correction group and 1.1 ± 2.0 mm in the posterior correction group (Table 2).

There was a positive correlation between the absolute corrections of the rib depression and Cobb angle in the coronal plane and the absolute corrections of the rib depression and the rib hump in patients treated by anterior instrumentation. A positive correlation was found between the absolute corrections of the rib depression and the rib hump in patients treated by the posterior instrumentation.

Other parameters

The average duration of the surgery was 154.4 ± 31.7 minutes for the anterior correction and 172.9 ± 42.2 minutes for the posterior correction ($P = 0.098$). The average volume of blood lost due to intraoperative bleeding was similar in both groups (442.1 ± 220.4 mL in the anterior and 471.4 ± 152.8 mL in the posterior correction group; $P = 0.663$). The average number of fused vertebrae of 6.0 ± 0.5 in the anterior correction group was significantly lower than that of 9.5 ± 1.6 in the posterior correction group ($P < 0.001$). After anterior correction, the patients were hospitalized for 10 ± 3 days on average, in comparison to 18 ± 23 days after the posterior correction ($P = 0.101$). In the anterior correction group, there was one case of prolonged pleural effusion, whereas in the posterior group there were two superficial infections. There were no neurological injuries in either group.

Discussion

This historic prospective study showed a better three-dimensional correction of the idiopathic thoracic scoliosis after the anterior than after the posterior correction. The relative coronal correction of the thoracic curve in our study was 78% in the anterior and 55% in the posterior correction group. With respect to the preoperative values of the Cobb's angle, a very good correction was achieved in the coronal plane by anterior correction. Betz (13) showed that the average correction in the coronal plane was 58% after anterior instrumentation and 59% after posterior instrumentation. In our study, a mild kyphotic effect was found in the anterior correction group, whereas it was not present in the posterior correction group. In both groups, the patients had normal values of the Cobb's angle in the sagittal plane after surgery. Rhee at al (25) analyzed the effects of anterior and posterior instrumentation in the sagittal plane and found a minimally kyphogenic effect of the anterior thoracic approach, whereas the posterior instrumentation showed a slightly lordogenic trend. Over time, these trends became more pronounced.

Relative correction of the apical vertebral body rotation in our patients was 62% in the anterior as opposed to 12% in the posterior correction group. Kaneda at al (26) demonstrated that correction in the horizontal plane after anterior instrumentation without the resection of the rib head was 15%, as opposed to 58% when resection was performed.

Our study showed that better correction of the rib hump was achieved after the anterior approach (71% vs 48% in the posterior correction group). Correction of the rib depression was almost the same in both groups, ie, 60% and 58%, respectively. Some studies showed that there was no correlation between the magnitude of the Cobb angle and the size of the rib hump before and after posterior instrumentation, as the radiologically visible correction of the thoracic curve did not imply a good correction of the rib hump (27,28). Our results showed the positive correlation between the absolute corrections of the Cobb angle in the coronal plane and the rib depression in the anterior correction group and between the absolute corrections of the rib hump and rib depression in both groups of our patients. The higher values of the Cobb angle in the coronal plane, rib hump, and rib depression before anterior instrumentation resulted in the better absolute correction of these values after surgery. When relative correction of these values was analyzed, such a correlation was not found.

On average, 3.5 fewer vertebrae were fusioned in the patients treated by the anterior instrumentation in our study. Giehl et al (10) emphasized the possibility of the selective fusion of the thoracic spine by the anterior instrumentation. Cochran et al (29) reported the highest prevalence of low back pain in the patients fused to L4 or L5.

Limitations of our study were a relatively small number of patients, long period of data collection, and a historic prospective study design. Since the follow-up was significantly longer in the posterior correction group, we can accordingly expect worsening of the scoliosis correction parameters in the anterior correction group after longer postoperative period. However, we believe that our results have shown that better correction of the deformity in the coronal and, especially, horizontal planes may be achieved by the anterior approach.

In the thoracic scoliosis correction, the mildly kyphotic effect of anterior instrumentation is welcome as most of these cases are hypokyphotic. Bone grafting during the anterior approach can prevent further worsening in the sagittal plane (8). The correction of the rib hump also has an important cosmetic effect, and it is better achieved by the anterior instrumentation. The results of this study show that anterior instrumentation offers greater possibilities of a three-dimensional correction in patients with idiopathic thoracic scoliosis.

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