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The Treatment of Large (>70°) Thoracic Idiopathic Scoliosis Curves With Posterior Instrumentation and Arthrodesis: When is Anterior Release Indicated?

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Study Design. Retrospective clinical study from 2 centers.

Objective. To analyze the efficacy of posterior instrumentation and arthrodesis for thoracic idiopathic scoliosis curves more than 70°.

Summary of Background Information. The increasing use of thoracoscopic techniques in deformity surgery has led several investigators to advocate anterior release followed by posterior instrumentation when treating "stiff" thoracic curves 60°–70°. To our knowledge, no study has been published to define indications for anterior surgery in thoracic idiopathic scoliosis.

Methods. This is a retrospective review of patients 20 years and younger, with idiopathic scoliosis and thoracic curves more than 70° treated with isolated posterior instrumentation and arthrodesis at 2 institutions from 1989 to 1999. A total of 50 patients were identified, and 46 were available for minimum 2-year radiographic follow-up. Of the 50 patients, 44 had bend films taken before surgery. All patients were treated with third-generation segmental spinal instrumentation using a varied combination of hooks, wires, and screws.

Results. Average patient age at surgery was 14.4 years (range 10–20), and average radiographic follow-up was 4.4 years (range 2–11.5). Average preoperative thoracic curve was 75° (range 70°–88°), and average bend was 47° (range 28°–60°), a flexibility of 37%. Average postoperative curve was 25° (range 10°–46°), and it was 27° (range 11°–46°) at latest follow-up, a correction of 64%. The average length of surgery was 6.15 hours, mean hospital stay was 8 days, and average blood loss was 1100 cc. The Scoliosis Research Society 22 or 24 was available at a minimum of 2 years in 46 of 50 patients. Mean domain scores were: pain 4.4, self-image 4.3, function 4.3, mental health 4.3, satisfaction 4.7, and total 4.4. Complications included 1 pseudarthrosis, 1 implant removal for prominence, and 1 implant removal for late operative site pain.

Conclusion. Using posterior surgery only, we have been able to at least equal the results reported in the literature by investigators using combined approaches. Isolated posterior instrumentation and arthrodesis achieve satisfactory cosmetic, radiographic, and patient-based outcomes in adolescents with idiopathic scoliosis with thoracic curves 70°–90°, without the added expense and morbidity of anterior release.

Key words: idiopathic scoliosis, large thoracic scoliosis, posterior surgery, thoracoscopic. **Spine 2005;30:1979–1984**

Historically, thoracic idiopathic scoliosis has been treated with posterior instrumentation and arthrodesis.[1,2] In 1962, Harrington[1] reported on 68 patients with thoracic curves, all treated with posterior surgery. King *et al*[2] reported on 405 thoracic curves in 1984, all treated with posterior surgery. Later studies with third-generation instrumentation showed slightly more use of sequential or staged anterior release. Lenke *et al*[3] studied 87 patients with thoracic curves, 4 treated with anterior release. Burton *et al*[4] analyzed 87 patients, only 1 of whom (134° curve) underwent additional anterior thoracic surgery.

The application of thoracoscopic techniques to spine surgery has led to several reports of its use in deformity surgery.[5–8] The indication in these studies for adding a thoracoscopic anterior release to posterior instrumentation in the treatment of scoliotic deformity was the treatment of a large, stiff curve or to prevent crankshaft. Average curve size in these reports ranged from 62° to 70°. The successful historical treatment of curves of this size with posterior instrumentation as well as our own experience led us to examine closely our results. The purpose of this study is to analyze the radiographic and patient-based outcomes of patients with adolescent idiopathic scoliosis and thoracic curves between 70° and 90°, treated with posterior instrumentation and arthrodesis.

Materials and Methods

This is a retrospective, clinical study of patients with idiopathic scoliosis and thoracic curves between 70° and 90°, treated with posterior instrumentation and arthrodesis at 2 centers, the University of Kansas, KS City, KS, and the Hospital for Special Surgery, NY, NY. Inclusion criteria included: (1) diagnosis of juvenile or adolescent idiopathic scoliosis, (2) younger than 21 years, and (3) thoracic curve between 70° and 90°. All patients treated at the University of Kansas from 1989 to 1999 were reviewed. A total of 38 patients were identified who met the

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inclusion criteria, and 37 were available for minimum 2-year follow-up. One patient who lived a distance away could not return for radiographic and clinical examination but did complete a Scoliosis Research Society (SRS) 22 at the 6-year follow-up. Records from the Hospital for Special Surgery were reviewed from 1994 to 1999. There were 12 patients identified who met the inclusion criteria, and 10 were available for minimum 2-year follow-up.

The angle of thoracic inclination (ATI)[9] was recorded on all patients at the University of Kansas before surgery and at latest follow-up. The SRS 22[10] or SRS 24[11] outcomes instrument was completed by 46 of 50 patients at latest follow-up or through recent mailing. Standing coronal and sagittal plane 36-in scoliosis radiographs were performed on all patients before surgery and 49 of 50 patients after surgery. Of 50 patients, 47 had radiographs available at minimum 2-year follow-up. Forty-four of 50 patients had recumbent active right and left bend radiographs before surgery.[12] Frontal curve magnitudes were recorded using the Cobb method.[13] Kyphosis was measured from T2 to T12 and lordosis from T12 to S1, using the Cobb method. Balance in the frontal plane was recorded as the offset of T1 from the central sacral line.[2]

All surgeries were performed on a Relton-Hall frame with somatosensory-evoked potentials monitoring. A standard midline posterior approach was performed. Autogenous posterior iliac crest, crushed corticocancellous allograft, or both were used in all cases. No patients were treated with a brace after surgery.

The selection of fusion levels and instrumentation technique has been described previously.[4,14] Correction technique varied between double thoracic, single thoracic, and double major curves. Double thoracic curves were treated with initial placement of the left-side rod, first securing the upper foundation with an intrasegmental claw, typically a down-going transverse process hook and an up-going facet hook at T2. An up-going facet or transverse process hook was then placed at T4. This connection was made with either an open hook or seating the hook using the drop entry feature of the Isola closed hooks. This procedure affords compression across the convexity of the upper thoracic curve. Multiple anchors along the concavity of the main thoracic curve were used. These were typically subpars wires or cables, but open hooks were also used. The lower foundation typically consisted of 2 or more pedicle screws.

After compression between the T2 claw and the T4 upgoing hook, the end of the rod was brought in proximity of the post of the lower foundation screw and the slotted connector placed on the post. A slight amount of distraction was then applied to the lower foundation. Some tightening of the concave anchors was applied at this point as well. The right-side rod was then placed, first securing the upper claw at T2 and using a down-going transverse process hook at T4, T5, or T6 to achieve distraction across the concavity of the upper thoracic curve. A cantilever correction maneuver is then used, connecting first to a periapical intersegmental transverse process claw and then bringing the end of the rod to the lower screw(s). Tightening of the concave anchors facilitates this correction maneuver.

For single thoracic curves, the sequence is quite similar, with omission of the T4 hooks used to compress/distract the upper curve. The left-side rod is placed, the upper foundation secured, and the rod brought to the lower screw foundation. The right-side rod is then set in the upper foundation, and a cantilever maneuver is used to bring the right-side rod to the lower screws. Tightening of the concave anchors facilitates this maneuver and finishes the correction of the apex of the curve.

For double major curves, the sequence is similar up to the point of placement of the right-side rod. Usually, at least 4 and sometimes 6 screws are used as the lower foundation in these curves. Once the right-side rod is placed, the slotted connectors are positioned on the rods in the desired transverse plane position. Additionally, any compression or distraction is used to level the lowest instrumented vertebra. It is imperative that the rods are parallel to one another and contoured in the desired sagittal plane position. The nuts are sequentially tightened. Because the slotted connectors are not perpendicular to the post of the pedicle screw, the tightening of the nuts will axially rotate the screws, thus affording a transverse plane correction of the vertebral bodies. Final tightening of the concave apex anchors is not performed until the lower curve is corrected. We believe that maximal correction of the lower curve is the top priority to create, hopefully, a healthy environment for the subjacent motion segments.

■ Results

Average patient age was 14.4 years (range 10–20), and average radiographic follow-up was 4.4 years (range 2.0–11.5). The average length of surgery was 369 minutes (range 210–683). Average blood loss was 1100 cc (range 600–2800 cc), and the average length of stay was 8 days (range 5–13). As part of the primary procedure, 13 patients underwent concave rib osteotomies,[15] 7 underwent convex thoracoplasties, and 4 underwent both.

Mean thoracic curve before surgery was 75° (range 70°–88°). Average bend film corrected to 47° (range 28°–60°) for an average flexibility of 37%. After surgery, the thoracic curve averaged 25° (range 10°–46°), a 67% correction. At final follow-up, it was 27° (range 11°–46°), a final correction of 64% (Figure 1). Mean thoracolumbar/lumbar curve before surgery was 48° (range 24°–81°), after surgery it was 21.7° (range 4°–42°), and at final follow-up it was 21.6° (range 2°–42°). The mean length of fusion was 11.7 vertebrae (range 8–15). No patient had symptomatic coronal or sagittal plane imbalance. For the 37 patients from the University of Kansas available for follow-up, ATI before surgery averaged 18° (range 9°–26°), and at last follow-up, it was 11° (range 5°–21°) (Table 1).

Through both mailings and clinic follow-up, the SRS 22 (43 patients) or SRS 24 (3 patients) was available in 46 of 50 patients, at an average follow-up of 5.4 years (range 2–11.7). The SRS 24 questionnaire does not contain a "Mental Health" domain. Within the individual domains, average scores were: pain 4.4 (range 2.6–5), self-image 4.3 (range 3–5), function 4.3 (range 2.6–4.8), mental health 4.3 (range 2–5), and satisfaction 4.7 (range 3–5). Mean SRS score (5 being the best) was 4.4 (range 3.2–4.96).

There were no deaths, neurologic injuries, or acute or delayed deep wound infections. Early in the series, 1 patient had a pseudarthrosis develop at the lower instru-

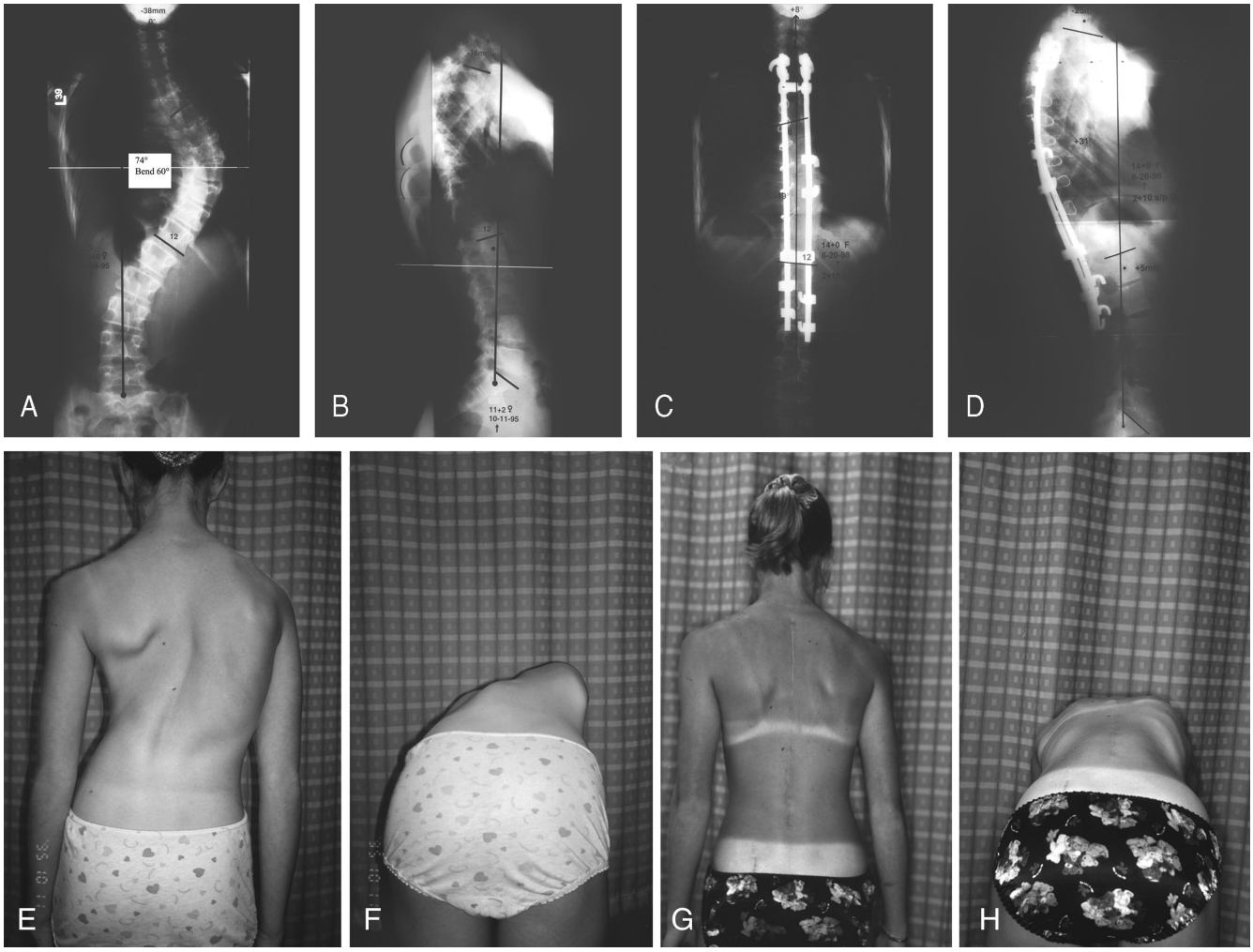

Figure 1. **A**, Preoperative posteroanterior. **B**, Preoperative lateral. **C**, A 2 + 10-year postoperative posteroanterior. **D**, A 2 + 10-year postoperative lateral. **E**, Preoperative photo standing. **F**, Preoperative photo bending. **G**, Postoperative photo standing. **H**, Postoperative photo bending.

mented level that was successfully treated with revision instrumentation and bone grafting. One patient developed lower hook dislodgement with prominence that required partial implant removal 5 [1/2] years after her index procedure. One patient required implant removal for late operative site pain.[16] The reoperation rate for any cause was 6%.

■ Discussion

Since the introduction of Harrington instrumentation in 1962, posterior instrumentation and arthrodesis have been the standard surgical treatment of thoracic idiopathic scoliosis.[1,2] Large stiff curves, frequently more than 100°, have been treated with additional sequential or staged anterior release.[3,4] The first reports of the use of thoracoscopic techniques for anterior release were published in the early and mid 1990s.[17–19] Since these early reports, many articles have been published on the use of thoracoscopic anterior release in the treatment of thoracic scoliosis.[5,7,20–31] Many studies included patients with mixed diagnoses. The indication for adding anterior release to posterior instrumentation and arthrodesis was the treatment of a large, stiff curve or to prevent crankshaft.

The crankshaft phenomenon, first identified by Dubousset in 1973,[32,33] occurs as a result of continued anterior column growth in the face of a posterior tether. Risk factors for its occurrence in patients with idiopathic scoliosis are age at surgery younger than 10 years[34,35]and surgery before peak height velocity.[36] Patients ≥10 years, even with open growth plates, appear to be at little risk for crankshaft[34,37] if operated on after peak height velocity.

The definition of how big or stiff a curve must be to warrant anterior surgery has not been addressed thus far. King *et al*[6] reported on 27 patients treated with prone position anterior release, and posterior instrumentation and arthrodesis with short-term follow-up. There were 19 patients who had a diagnosis of idiopathic scoliosis and 1 neuromuscular scoliosis. Average patient age was 14 years (range 7−19), and average thoracic curve was 70° ± 11.6°. Average initial postoperative curve measured 23° ± 9°, a correction of 67%.[6]

Table 1. Patient Data

Patient No.	Liv	Rib Ost	Thoracoplasty	Preop Cobb	Thoracic Bend	Preop ATI	Bend Diff	% Corr	Postop Cobb	Final Cobb	% Corr	Final ATI	ATI Corr
1	12		R6−10	84	50	24	34	40.5	40	48	43	20	17
2	14			80	38	21	42	52.5	15	11	86	9	57
3	13			76	56	24	20	26.3	23	20	74	17	29
4	14	L5–L10		76	37	20	39	51.3	20	16	79	12	40
5	15	L6−11		74	56	17	18	24.3	17				
6	13	L6−10		72	50	12	22	30.6	27	31	57	9	25
7	13	LT5–T10		70	42	17	28	40.0	21	20	71	5	71
8	14			70	40	14	30	42.9	20	18	74	5	64
9	15			70	30	15	40	57.1	30	35	50	14	7
10	12	LT6–T10		70		19			30	32	54	13	32
11	12	LT6–T11		70	40	14	30	42.9	20	14	80	5	64
12	14			87	55	16	32	36.8	18	22	75	8	50
13	13			70	48	28	22	31.4	10	14	80	5	82
14	12			74	49	19	25	33.8	29	30	59	9	53
15	15			80	60	16	20	25.0	24	18	78	12	25
16	14	R6−10		73		25			15	14	81	12	52
17	15			84	55	20	29	34.5	40	36	57	20	0
18	14			76	47	23	29	38.2	33	25	67	17	26
19	13	L5–L10		70	54	19	16	22.9	21	33	53	12	37
20	12			72	49	23	23	31.9	26	46	36	21	9
21	12	LT6–T10	RT3–T11	76	58	19	18	23.7	34	34	55	18	5
22	14			70	36	10	34	48.6	17	16	77	6	40
23	14			77	48	18	29	37.7	11	25	68	12	33
24	11			73	40	16	33	45.2	25	26	64	7	56
25	15			74	52	18	22	29.7	29	36	51	5	72
26	13			72	57	20	15	20.8	37	32	56	14	30
27	14			70	40	18	30	42.9	18	20	71	10	44
28	15			73	54	15	19	26.0	31	35	52	10	33
29	14	L5–L10	R6–10	75	60	20	15	20.0	16	27	64	9	55
30	13	L5−10	R6−10	75	60	23	15	20.0	25	24	68	18	22
31	14			71	46	9	25	35.2	31	26	63	9	0
32	14	L6−10	R6−10	74		26			20	30	59	13	50
33	15			71		15			16	22	69	12	20
34	13		R8−10	75	41	20	34	45.3	27	33	56	12	40
35	14	L6−10		70	46	15	24	34.3	20	32	54	8	47
36	14			75	40	15	35	46.7	14	18	76	6	60
37	14		R T6–T11	78	50	20	28	35.9	23	24	69	14	30
38	13	L7–L10		76	56	20	20	26.3	27	26	66	5	75
39	16			88	58		30	34.1	46	32	64		
40	15			75	28		47	62.7	23	23	69		
41	14			78	60		18	23.1	31	33	58		
42	14			75	40		35	46.7	37	34	55		
43	15			72	38		34	47.2	28	30	58		
44	13			71	45		26	36.6	12				
45	14			80	40		40	50.0	31				
46	15			70	35		35	50.0	21	29	59		
47	15			80	45		35	43.8		30	63		
48	13			80	35		45	56.3	35	35	56		
49	15			75			75		33	39	48		
50	15			75			75		36	32	57		
Average	13.8			74.8	46.9	18.5	30	38	25	27	63	11.2	39

Corr, correction; Diff, differential; Liv, lower instrumented vertebra; Ost, osteotomy.

Newton *et al*[5] reported on 65 patients, 13 with idiopathic scoliosis and 35 with neuromuscular scoliosis, treated with sequential anterior thoracoscopic release and posterior instrumented arthrodesis. Average patient age in the entire series was 14 years (range 2−22). Average preoperative scoliosis was 62° ± 17°, and at 1 year was corrected to 29° ± 16°, a 53% correction.

Niemeyer *et al*[7] studied 17 patients with idiopathic scoliosis. They stated the indication for anterior surgery in 11 patients was insufficient flexibility. Average patient age in this group was 17.5 years (range 14−26), and average curve size was 69° (range 48°−90°), with a mean flexibility of 26.7%. Average final correction was 39.4° or 42.8%. Six patients were operated on anteriorly because of concern over crankshaft. Their average age was 10.5 years (range 5−13), and their preoperative curve and curve correction were 48° and 42.9%, respectively.

To our knowledge, this is the largest series of patients with idiopathic scoliosis and large thoracic (>70°) curves treated with posterior instrumentation reported in the literature. It is composed of patients from 2 centers and 4 different primary surgeons. Our average curve size (75°) is larger than average curve size in the 3 large series just cited.[5–7] Our average curve correction of 64% at

4.4-year follow-up compares favorably to those series as well.

Of the 37 patients in our series with preoperative and latest follow-up thoracic ATI measurements, average ATI correction was 39% at an average 4.4-year follow-up. This result is consistent with our previous report that trunk deformity correction is maintained at intermediate term follow-up[38] with torsional instrumentation techniques. Thus, despite large, stiff curves, cosmesis can be improved by posterior instrumentation alone. This effect is also reflected in the SRS 22 questionnaire because the self-image domain mean score was 4.3, satisfaction domain was 4.7, and the mean total was 4.4 of a possible score of 5.

Other recent reports have also shown satisfactory treatment of large scoliotic deformities with posterior surgery only. Arlet *et al* treated 15 patients with idiopathic scoliosis, with an average thoracic curve of 78° treated with posterior surgery only. These investigators were able to achieve an average correction of 54% at a minimum of 2 years. Chang[40] has reported on 40 patients with large (average 98°) thoracic curves treated with posterior surgery alone. He showed an average correction of 67% at a minimum of 2 years.

Innovation in medicine must be encouraged and allowed to flourish. However, as with any innovation, the risks and benefits, as well as indications for its use must be defined. Thoracoscopic spine surgery is certainly an advance that is here to stay. Its developers and early advocates have clearly shown that it can be performed safely and, in many instances, is preferable to open thoracotomy.[28] However, what have not been well defined are the appropriate indications for its application. This study has addressed this question by showing that curves between 70° and 90° do not need anterior release to achieve good results. In conclusion, this retrospective, 2 center series of patients with idiopathic scoliosis and thoracic curves between 70° and 90° has shown that these patients can be effectively treated without anterior surgery and have good radiographic, cosmetic, and patient-based outcomes.

■ Key Points

- Thoracic idiopathic scoliosis curves of 70°−90° can be effectively treated (63% correction) with posterior surgery only.
- ATI correction of 42% was maintained at 4.4-year follow-up.
- Patient satisfaction as assessed with SRS 24 or 22 is high (4.4 of 5) at more than 4 years of follow-up.

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