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Transverse process wiring for thoracic scoliosis

A new technique

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ABSTRACT We describe a method of reducing neurological risk by avoiding neural elements when performing segmental spinal fixation for scoliosis. This was done by making use of the transverse processes of the thoracic vertebrae 1-11 and wired plates. The wires are prevented from cutting the bone by attaching them to rectangular plates. These wired plates on the two sides of each segment should be firmly fixed to the base of the transverse process by tying them to each other. Maximum correction is obtained by spreading the force applied by stabilizing each thoracic vertebra from both sides. Derotation is attempted when all the wires have been tightened. Tension forces are spread to all fixated vertebrae simultaneously and the correction should be carried out at all levels at the same time. On the convex side, each wire connects over the rod to the next one above it and, tightened one by one, provides compression.

We treated 15 patients having a thoracic curve with this method and followed them for 25–39 months. In 2 cases of congenital scoliosis, a 50% correction was obtained. In 3 cases of neurofibromatosis scoliosis, a 55% correction was achieved. In 10 cases of idiopathic scoliosis, the correction was 60%. When the thoracic sagittal contour was evaluated, thoracic kyphosis, which had been between –20° and +90°, had improved to between +8° and +43° in all cases. No infection or neurological complications occurred.

The Harrington technique for the correction of deformities of the spine introduced a new era in the surgical management of scoliosis (Renshaw 1988).

The Luque (1982) technique for segmental fixation of the spine, using wire loops around the laminae with two contoured paravertebral rods, allowed rigid fixation for correction of scoliosis without the use of postoperative external support. Luque has also reported correction of the sagittal contour using this technique.

Drummond (1988) has employed the spinous processes for segmental spinal fixation without the added risk of sublaminar wires, and has reported generally good results without using postoperative immobilization. He pointed out that his technique was ineffective in kyphoscoliosis.

Harrington's technique involves fixation at each end of the curve and Luque's involves fixation at all levels, but Cotrel-Dubousset uses fixation of strategic vertebrae only. Cotrel-Dubousset (Cotrel et al. 1988) reported that in all cases they obtained normal physiological values in sagittal contour with three-dimensional correction by developing the derotation technique. Asher et al. (1992) have introduced the Isola system. In addition to the hook-screw, they used a lateral translation technique with sublaminar or subpars wiring, and reported the same effect. Good postoperative results have been reported, with CD-instrumentation and other newer multiple hook and rod systems, but some loss of correction occured (Stasikelis et al. 1988b, Lenke et al. 1992, Richards et al. 1994, Wimmer et al. 2001).

Fixation of the transverse processes by means of wire was first done in 1971 by Stener in the treatment of a vertebral tumor (Stener 1971). Starting from this method, we aimed to perform segmen-

Data on 15 cases

									Scoliosis (°)					Kyphosis (°)			
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	15	F	AIS(KIII)	3	1	–	T2–L2	37	45	25	14	68	–	63	33	–	
2	17	F	AIS(KIII)	10	2	+	T1–L1	33	130	98	70	46	–	78	43	–	ant + post 1 wire broke (upper)
3	20	F	AIS(KIII)	4	2.5	–	T1–L1	32	67	54	25	62	–	70	30	10	3 wires + 1 TC broke (upper)
4	18	F	AIS(KIII)	4	2	–	T1–L1	31	50	38	16	68	–	26	28	–	1 TC broke (lower)
5	11	F	AIS(KIII)	4	1.5	–	T3–L1	31	62	40	23	62	–	25	30	–	
6	13	F	AIS(KIII)	4	1.5	–	T2–L1	30	60	34	20	66	–	16	26	–	1 TC broke (lower)
7	11	F	AIS(KIV)	3	1	–	T2–L1	30	52	36	30	42	8	46	24	–	Boston brace was applied
8	20	M	AIS(KIII)	5	1	+	T3–L2	26	65	53	30	53	–	30	25	–	
9	15	M	AIS(KIII)	1	0.5	–	T2–L2	26	35	16	10	71	–	90	30	–	
10	16	M	AIS(KIII)	5	1	+	T3–L2	25	70	50	28	60	–	26	20	–	
11	11	F	NF–1	3	1	–	T3–L1	31	53	36	28	47	–	40	32	–	
12	8	F	NF–1	4	1	–	T1–L1	30	60	32	30	50	–	0	26	–	
13	12	F	NF–1	6	1.5	+	T2–L1	27	70	44	21	70	–	58	22	–	
14	15	F	CON	5	1	+	T2–T11	39	60	51	34	43	–	22	26	–	
15	12	F	CON	6	2	–	T1–L2	25	78	60	32	58	–	–20	8	–	ant + post

K King classification, NF–1 Neurofibromatosis, CON Congenital, TC Transverse connector, ant + post anterior + posterior surgery

A Case
B Age (year)
C Gender
D Type of curve
E Preoperative gibbosity (cm)
F Postoperative gibbosity (cm)
G Thoracoplasty
H Fusion levels
I Follow-up (mo)
J Preoperative
K Side bending
L Postoperative
M Correction (%)
N Loss of correction (°)
O Preoperative
P Postoperative
Q Loss of correction (°)

tal spinal fixation with wired plates by using the transverse processes of thoracic vertebrae and reducing neurological risks by avoiding neural elements. In 1994, we started to use fixation with wired plates on the transverse processes instead of the sublaminar wiring in the techniques of Luque, Harrington-Luque and that described by Asher. By 1998, we came to the conclusion that transverse process wiring using wired plates in combination with transpedicular screws constituted a substantial advance in thoracic scoliosis surgery and we developed the technique, which we describe here.

Patients and methods

Our system can be used on the thoracic component of the scoliotic deformity. However, we have also used this technique effectively together with the hook-screw combination in scoliosis involving lumbar and sacral components. Since 1998, we have performed 45 scoliosis operations using this technique. To show the corrective effect of our technique, we describe 15 types of thoracic scoliosis, in which the technique was applied alone, with a minimum follow-up period of 2 years (mean 30 (25–39) months) (Table). All operations were done by the same surgeon (NE). Facet and lamina fusion were performed together by using an autograft and allograft together. Anterior release was carried out in 2 cases in the same sequence because one of them was very severe and rigid, the other was congenital and had a wedge vertebra causing severe thoracic lordosis (–20°), and a wedge vertebrectomy was performed. All the patients were given cefazolin and gentamicin, beginning just before the skin incision and continuing two days after the operation. Preoperative evaluation of all patients was standardized and included a neurological and routine blood evaluations, posteroanterior and lateral standing radiographs and right and left supine maximum bending radiographs, MRI and electrocardiogram. Thoracic kyphosis was measured with Cobb's angle between the uppermost discernible

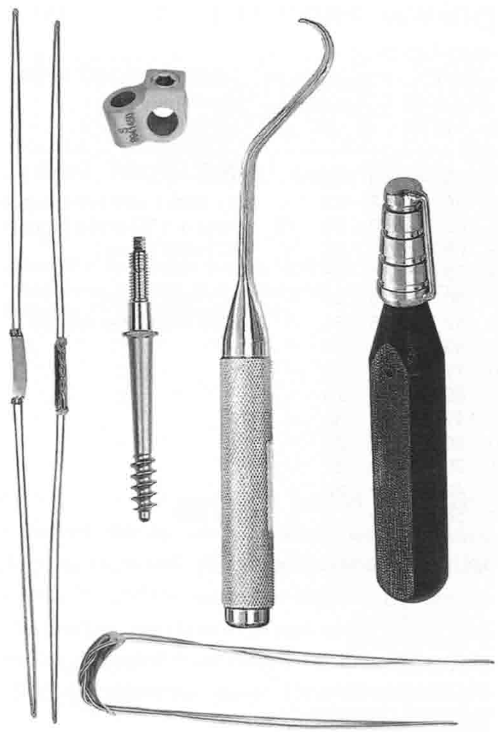


Figure 1. Wired plate, connector, transpedicular screw, transverse process elevator and wire bender are shown.

vertebral body (usually T5) and the inferior edge of T12. Thoracic gibbosity was assessed by direct measurement of the rib hump in the forward bend test (Adam's test). Thoracoplasty was performed in 5 cases with a severe rib hump.

When the patients became pain-free and felt comfortable, they were mobilized without external support, generally on the second or third day after the operation. They performed the activities of daily life after 3 weeks. Sports activities were not allowed for 6 months. After 6 months, all activities were permitted, except for strenuous competitive sports and heavy work.

Technique

Implants. Implants were designed and developed by the first author (Figure 1). 2 holes were made at either end of the rectangular plate, that had a thickness of 0.5 mm, length 30 mm and width 5 mm. Cerclage wires (1.2 mm) were passed through these holes, and their ends were welded together. The plate was bent so as to leave the side with the wires convex. Thus, the wire was prevented from cutting into the bone and the force on the bone was spread over a larger area. A transverse process elevator was designed to prepare the base of the transverse process, and a device was designed to bend the tips of the wires so that they could easily pass under the transverse process. The screws designed were conical and had spongelike threading at their tips, extending over 1/3 of their length. The connection between the screws and the rod was provided by a connector. Rods with a smooth surface and a diameter of 6 mm were used. The wired plate was made of stainless steel, the others were made of Ti-6Al-4V and manufactured by Hipokrat Company in Izmir,Turkey.

Surgical technique. A standard subperiosteal exposure is made. The lower screw sites are prepared. 4–6 transpedicular screws are inserted at vertebral levels, which are predetermined as appropriate. If no transpedicular screw has been inserted into T12, this site is left out because the T12 transverse process is rudimentary and not suitable for locating the wired plate. This finding is sometimes present in the T11 transverse process as well. T11 transverse processes on both sides are exposed by electrocautery. At this level, facet decortication is carried out. The posterior spinous process is removed at its base and lamina decortication is performed. The main point should be to avoid weakening or destroying the edge joining the transverse process and the lamina. Using the transverse process elevator, the site is prepared under the transverse process, and between the transverse process and the rib (costotransverse space), taking care not to enter the bone, but to cut around it. This procedure resembles the placement of hooks on the transverse process.

The tip of the wire is bent into the right shape with the specially-designed wire-bending device. It is then passed under the transverse process, starting caudally and working cranially or vice versa in accordance with the surgeon's preference and the anatomical findings. The tip of the wire is pulled from the far side and held against the undersurface of the transverse process, so that the plate reaches its base (Figure 2). The same procedure is used on the other side of the same vertebra. The welded ends of the wires are then cut on each side of the vertebra. Thus, 4 wire tips are exposed on each side. 2 pairs of wires diagonally opposite are

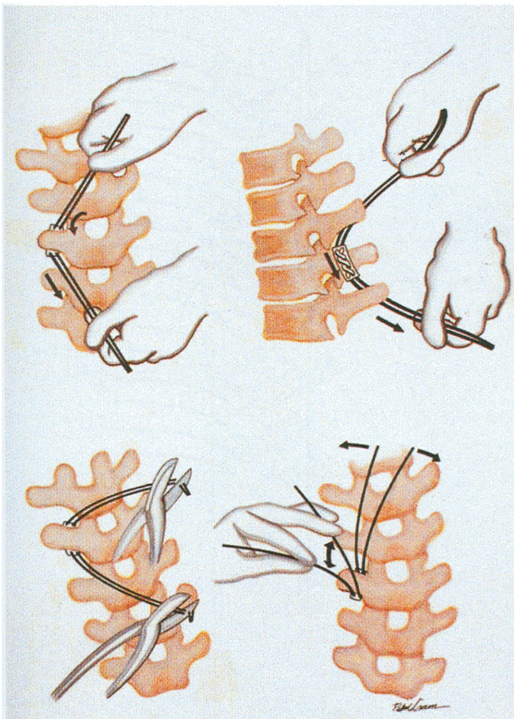


Figure 2. The tip of the wire is bent into an oval shape and then passed under the transverse process. It is pulled from the other side and held against the under-surface of the transverse process, so that the plate reaches its base The welded ends of the wires are then cut, thus, four wire tips are exposed on each side.

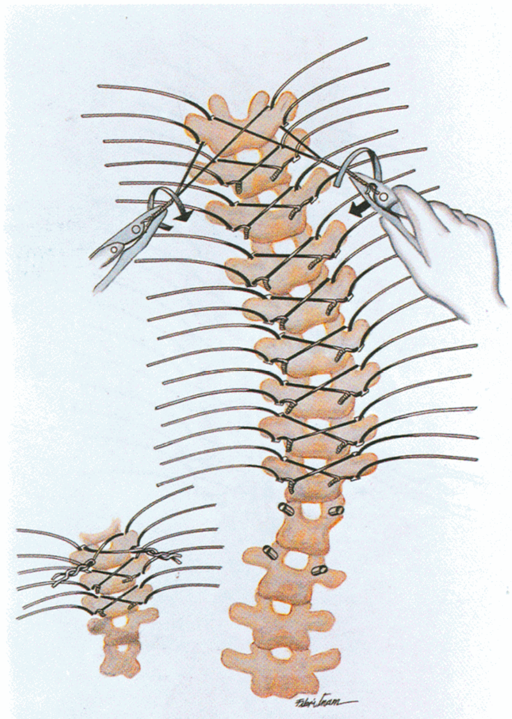


Figure 3. 2 pairs of wires diagonally opposite each other are twisted together, forming an X across the vertebra. These wires are tightened on the caudal edges of the transverse processes on each side and the excess is removed. This is done on each vertebra so that the wired plates on each side are firmly connected with each other and grasp the vertebra via the transverse processes. The remaining two wires are left free in order to be tightened to the rods.

twisted together to form an X across the vertebra (Figure 3). These wires are tightened on the caudal edges of the transverse processes on each side and the excess is removed. The operation ensures that the wired plates are firmly fixed to the base of the transverse process. This procedure is repeated on each vertebra so that the wired plates on each side are firmly connected to each other and grasp the vertebra via the transverse processes. The remaining two wires are left free in order to be tightened to the rods. This is done to each vertebra until the upper end has been reached.

Next, the wires on the concave side are separated from each other. The rod is contoured to the shape of the scoliosis and to that of the anticipated sagittal contour and placed with a sufficient number of connectors on the screws and between the separated wires, in accordance with the curve of the vertebrae. Each pair of wires is tightened to the rod one by one, from the caudal to the cranial end (Figure 4). Thus, the wires are fixed to the rod without tension and no load is placed on the wire or the transverse process. If the curve is severe, the rod may not move into line with the vertebrae because we proceed in a cranial direction. In this case, an assistant pushes the rod towards the vertebrae close to the transverse process, and the surgeon tightens the wires. When the tightening process is finished, the assistant releases the pressure on the rod. With the removal of the force, the first correction is assessed. Next, the rod is rotated through 90 degrees from its scoliotic configuration to a kyphotic one, and fixed in this position by tightening the connector screws (Figure 5). This is the second corrective effect.

On the convex side, the rod is contoured to less kyphosis than the patient's, so as to push the convexity forwards during instrumentation. The

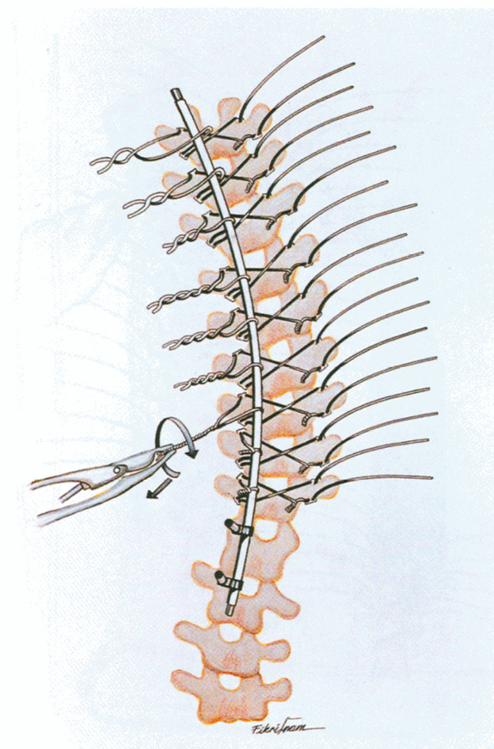


Figure 4. The wires on the concave side are separated from each other. The rod is contoured to the shape of the scoliosis and to that of the anticipated sagittal contour and placed on the screws and between the separated wires according to the curve of the vertebrae. Each pair of wires is tightened to the rod one by one, from the caudal to the cranial end.

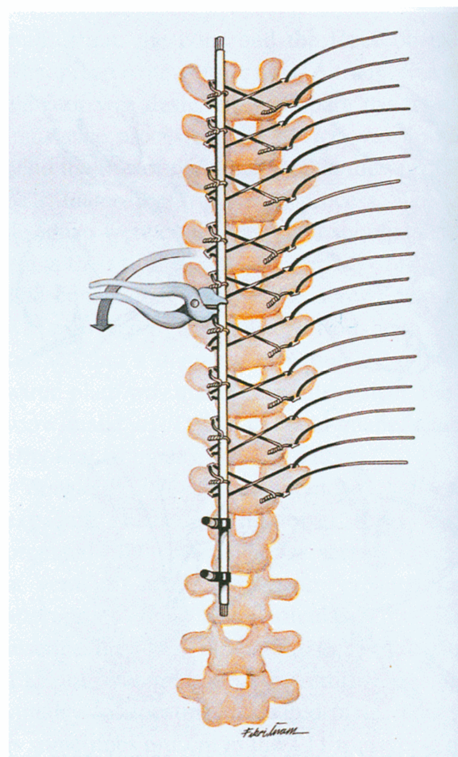


Figure 5. The rod is rotated 90° from its scoliotic configuration to a kyphotic one, and fixed in this position by tightening the screws.

remaining unattached wires are separated from each other. The rod is located on the screws, which are tightened. Then, each wire is connected over the rod to the next one above it, starting caudally and working cranially. When the pairing procedure is completed, one wire remains at each end of the rod. These are twisted into the nearest pair, thereby forming a group of three wires at the uppermost and lowermost vertebrae. All the wires are tightened one by one in a caudal to cranial direction while the assistant pushes the rod down at its upper end on to the spine and maintains its position (Figure 6). Releasing the rod after all the wires are tightened brings about the third corrective effect. Here, a compression effect is produced on the convex side by the wires joined over the rod to the ones above and below. By joining the rods with a transverse connector at each end, a rectangular configuration is obtained and overall strength, especially during torsion, is increased (Figure 7). Bone grafts are placed on the decorticated facet joints and on the lamina over the crossed wires.

In congenital anomalies of the vertebrae, transverse processes are involved as well. Hypoplasticity and/or conjoining of transverse processes limit the placement of the wired plates on them. In such cases, the application of hooks to deformed apex vertebrae and their use together with wired plate application at other levels solves the problem.

Results

In 2 cases with congenital scoliosis, a 50% correction was obtained. In 3 cases with neurofibromatosis scoliosis, a 55% correction was achieved. No loss of correction occurred in either group of patients. In 10 cases of idiopathic scoliosis, the median preoperative curve was 61 (35–130)°; correction as shown on the preoperative side-bending

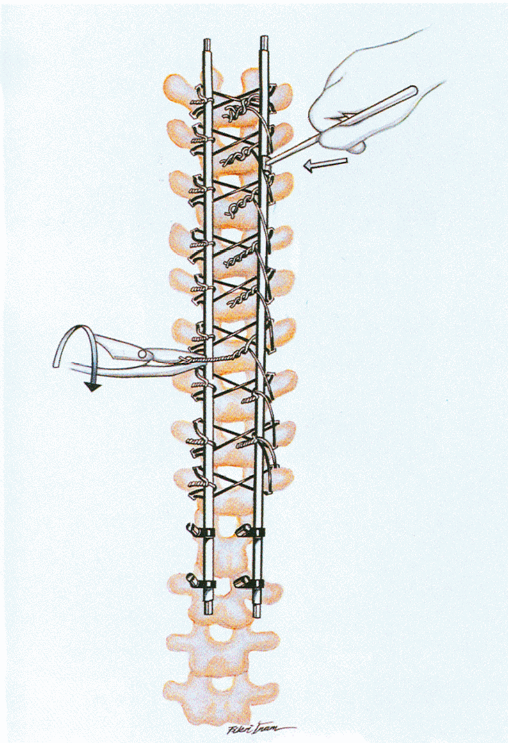


Figure 6. On the convex side, the rod is contoured to less kyphosis than the patient's, so as to push the convexity forwards during instrumentation. The remaining unattached wires are separated from each other. The rod is located on the screws, which are tightened. Then, each wire is connected over the rod to the next one above it, starting caudally and working cranially. When the pairing procedure is completed, one wire remains at each end of the rod. These are twisted into the nearest pair, thereby forming a group of three wires at the uppermost and lowermost vertebrae. All the wires are tightened one by one in a caudal to cranial direction while the assistant pushes the rod down at its upper end on to the spine and maintains its position.

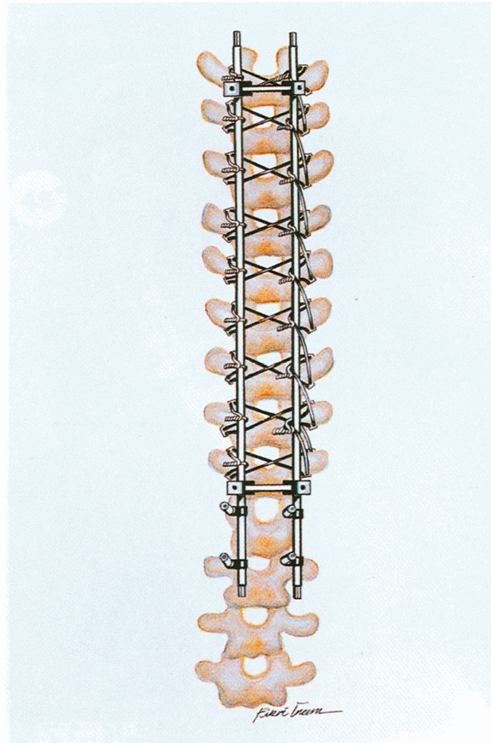


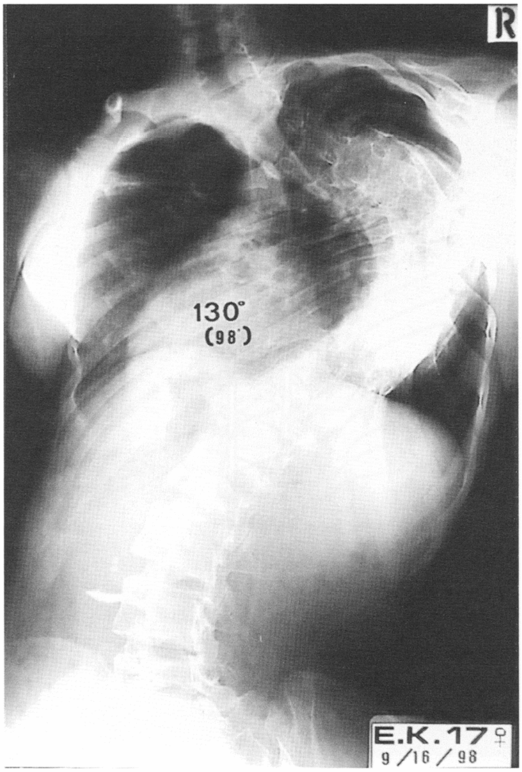
Figure 7. By joining the rods with a transverse connector at each end, a rectangular configuration is obtained and overall strength, especially during torsion, is increased.

radiographs was a median of 39 (16–98)°, while the postoperative correction on standing radiographs was a median of 24 (14–70)°. Thus, a 60% correction was obtained. No loss of correction occurred after an average of 30 months of follow-up in this group, except in patient no. 7, who had an 8° loss of correction was observed after a follow-up of 23 months. This was a King IV type idiopathic scoliosis and since the patient was very young, only the thoracic part of the curve had been corrected and instrumented, not the lumbar one. When the curve in the uninstrumented lumbar part started to increase, a Boston brace was applied.

In all cases, when the thoracic sagittal contour was evaluated, thoracic kyphosis, which had been between –20° and +90° preoperatively, had improved to between +8° and +43° postoperatively. In case 3, broken wires and the tips of the rods were removed where three wires on the upper-end vertebrae had broken, and a resulting increase of 10° in the kyphosis was observed (40° kyphosis at last examination). No loss of correction was seen in the other patients.

In 7 cases with idiopathic scoliosis in whom thoracoplasty was not performed, a 56% correction in thoracic gibbosity was achieved.

The complications included 4 broken wires in 2 patients and 3 broken transverse connectors in 3 patients. The transverse connectors have been redesigned. Since then, no further breakages have occurred. No infection or neurological complication developed in any of the cases.



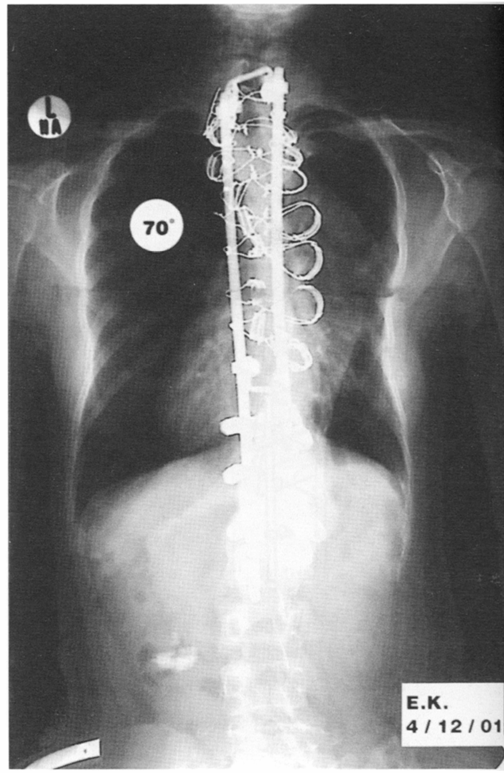


Figure 8. Standing AP radiograph showing a right thoracic idiopathic curve (130°) in a 17-year-old girl who had a 98° correction on the lateral bending film (A).

Result at 30 months postoperatively (anterior release in the same sequence) showing a reduction in the scoliosis to 70° with no loss of correction (B).

Discussion

It has been agreed that sublaminar wiring is associated with the highest risk for neurological complications among all the techniques used (SRS Morbiditiy Report 1987). A system has been designed to reduce the intraoperative risks (Segal and Schwentker 1994). These neurological complications may occur in the late phase (Bernard et al. 1983). In CD and other newer multiple hook systems, thoracic hooks, which are placed in the caudal direction, are canal-invasive and it is difficult to control all the hooks during rotation of the rod. Denis (1988) pointed out that the specific high-risk steps in a CD procedure are primarily the lower intermediate hook in the concavity because it may be too large or the laminotomy too big, which causes the hook to enter the dura. A distraction system has been designed for this undesired effect (Stasikelis et al. 1988a). The main advantage of our technique is that the protective cover over the medullar canal (ligamentum flavum and lamina) is not disturbed. The procedure of locating the wired plate is the same as that of placing a hook on the transverse process, and no neurological risks have been reported. During distraction, distractive force is exerted on all tissues including the spinal cord. Interruption of the blood supply to the cord is thought to cause paralysis (Transfeldt 1994). With our technique, no distractive force is used. Denis (1988) pointed out a possible risk in a patient with severe kyphosis in placing a hook at the apex of the kyphus and levering it into the spinal canal while trying to reduce the kyphosis. Since no hooks are used with transverse process wiring, there is no such risk. Thanapipatsiri and Chan's study (1996) showed that the thoracic transverse processes of T1-T10 are safe structures for the implantation of anchorage in posterior spinal instrumentation and can be used without adverse effects on adjacent tissues. Gayet et al. (1999) also reported in their DMD scoliosis series that the transverse processes

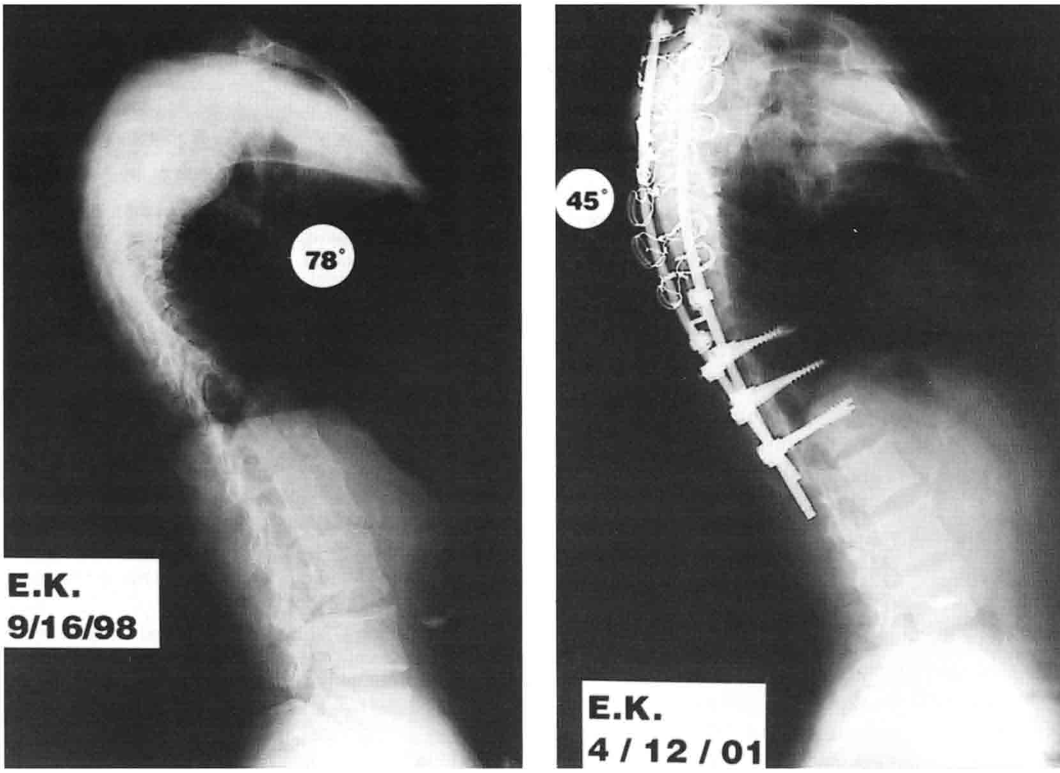


Figure 9. Preoperative lateral radiograph of the same curve with a kyphosis of 78° (A). 30 months postoperatively restoration of normal kyphosis of 45° can be seen (B).

of thoracic vertebrae were safe and effective structures. Theoretically, the technique is not likely to cause risks, except from the transpedicular screws fixed on the lower-end vertebrae, which are usually neutrally rotated and undeformed. Since 1994, we have performed wired plate insertion in various types of conditions, including fracture, Pott's disease, tumor (in these cases we used wired plates instead of thoracic hooks placed in a caudal direction), as well as on 52 scoliosis cases. We have had no neurological complications related to wired plate insertion.

Scoliosis is a three-dimensional deformity and the correction should be able to correct the deformity in all these dimensions. Traditionally, the rate of surgical correction in frontal plane deviation in idiopathic scoliosis is 40–70% (Akbarnia 1988, Stasikelis et al. 1988b, Mielke et al. 1989, Lonstein 1994). We obtained a 60% correction in 10 cases of idiopathic thoracic scoliosis. The thoracic kyphosis achieved was between +20° and +43°. Rotational correction has not been evaluated in our study. Nevertheless, we believe that the use of rod rotation without distraction and fixation of all segments affects the rotation deformity positively. Dickson and Archer (1987) reported that the greatest rotation occurs in the apical vertebra. Therefore, these vertebrae should be instrumented as with our technique. Placement of the wires very close to the rotational axis in sublaminar wiring prevents the derotation effect. For this reason, subpars wiring was introduced (Asher et al. 1992). Cotrel-Dubousset (Cotrel et al. 1988) pointed out that a pedicular hook is much more effective in derotation because of the longer lever arm.

In our technique, they are much farther away from the mid-axis line than in all the other techniques since the wires are placed around each transverse process through the costotransverse space from T1 to T11. During rotation of the rod, the tension forces are simultaneously spread to all the instrumented vertebrae and the correction procedure is carried out at all levels at the same time. Thus, from the small forces operating on each vertebra, the total force of correction is very large. In transverse process wiring, the force is applied to the vertebrae over a much wider area than in the other techniques, which in theory increases the rotational correction effect. Cotrel-Dubousset (Cotrel et al. 1988) pointed out that the insertion of the convex rod adds another force directed medially and forward to the apical vertebra, increasing the force produced by the rotation of the concave rod as well as the derotation of the vertebrae. On this convex rod, alternate compression is applied between the end and intermediate vertebrae. With the present technique, we follow the same rules, but using fixation from each segment and applying compression between all the segments. To our knowledge, no other technique using wire fixation so far reported has a compression effect on the convex side.

The main purpose of treatment in scoliosis is to correct the curve as much as possible and to maintain this correction by fusion. The rate of fusion in rigid fixation has gradually increased. The quality of the fixation, and thus its rigidity, is attributable to the greater number of fixation points with reduced hook dislodgment and less loss of correction at follow-up (Lonstein 1994). Since we have not used hooks and have made fixations at all levels, we have achieved good quality of fixation with a sufficient fusion area of both facet and lamina. We have used no postoperative immobilization and have seen no loss of correction, except in one case mentioned above.

In our experience, the duration of surgery is shorter than with segmental spinal osteosynthesis, but longer than the other techniques. Removal of metal would probably be difficult with so many wires in the fusion mass. It seems possible that some wire parts would have to be left in the fusion.

In conclusion, transverse processes of T1-T11 are safe and strong structures for use as fixation points for posterior spinal fixation. We think that thoracic transverse process wiring is effective in thoracic scoliosis surgery.

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