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Adolescent idiopathic thoracic scoliosis: apical correction with specialized pedicle hooks

Received: 1 July 1998
Revised: 25 March 1999
Accepted: 21 April 1999

Study conducted at the Shriners Hospital for Children and the Montreal Children's Hospital, McGill University, Montreal, Quebec, Canada. No support of any source was received for the completion of the study.

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Abstract Forty-one patients with thoracic adolescent idiopathic scoliosis (AIS) treated with only a posterior spine fusion using specialized pedicle hooks (SPH) (hooks augmented with 3.2-mm screws) at the apex of the curve were reviewed in order to assess the effectiveness of this correction method. Inclusion in the study group required a minimum of 2 years' follow-up and the same strategy of correction where the apical vertebrae (3 or 4 vertebrae on the concave side) were instrumented with SPH. The mean preoperative Cobb angle was corrected from 55° (42°–80°) to 18° (67%) postoperatively and to 23° (58%) at the last follow-up (28–50 months) for a flexibility index of 46%. Apical vertebral translation was corrected to 70% at the last follow-up. Thoracic kyphosis remained unchanged, from 23° to 26°, and the lumbar lordosis

went from –53° to –59°. The lumbar curve was corrected from 38° to 18°. Coronal balance improved from 10 to 1 mm; shoulder balance was improved from 15 to 5 mm. The rib hump was improved from an average of 30 mm preoperatively to 15 mm postoperatively, but only to 25 mm at the last follow-up (17% of correction). One case of a spastic bladder was observed postoperatively, which resolved completely after 8 months. Three patients had to have their instrumentation removed because of pain. There was no complication related to the use of the SPH. The authors conclude that apical correction with SPH allows effective scoliosis correction without spinal distraction and does not require supra- or infralaminar hook in the spinal canal.

Key words Scoliosis, operative procedures

Introduction

The most rigid part of a thoracic scoliosis is situated at the apex, where most structural and rotational changes have occurred. The apex was ignored for a long period during time of the Harrington instrumentation, where only the two most distant vertebrae were instrumented [12]. In the 1980s surgeons started to instrument closer to the apex to achieve better correction. Cotrel and Dubousset used a multihook system anchored on strategic vertebrae to achieve correction by rotation of the concave rod [8, 9].

However the apical vertebra(e) was (were) not instrumented on the concave side (side of the correction). At the same time Luque described his concept of segmental instrumentation including all vertebrae using sublaminar wires [19]. The Harrington-Luque concept ensued, where sublaminar wires were passed under the apical vertebrae onto the Harrington rod to improve correction of the translation [25]. However, neurologic concern due to the sublaminar wires [6, 18] prompted some authors to use a segmental spinous process wiring at the apex of the curve [10]. All these methods of correction gave a percentage Cobb angle correction of between 45 and 66% [3, 9, 15,

Fig. 1 Postero-anterior and lateral close-up radiographs of the specialized pedicle hook (SPH). It is stabilized with its 3.2-mm screw going into the pedicle

21–23, 27, 28]. In 1995 Suk et al. reported on the use of a pedicle screw at each level on the concave side and at every other level on the convex side [24]. With this they achieved a rigid segmental fixation of the apex and of the whole curve. They reported a 72% correction rate. Their

superior correction could be explained by the rigid fixation achieved with pedicle fixation and the number of vertebrae instrumented. However, neurologic concern still remains with the use of pedicle screws [20]. Specialized pedicle hooks (SPH), where the pedicle hooks are augmented with 3.2-mm fixation screws were devised as an alternative to pedicle screws in the thoracic spine (Fig. 1). They have been reported to achieve a fixation close to the strength of pedicle screw fixation [6]. The use of such SPH at the apex of the curve was previously described by ourselves in a preliminary report [1], where the technique of insertion is extensively detailed. Using such implants at the apex of the curve we were able to achieve in our preliminary report a correction of 63% of the Cobb angle. The purpose of the present study was therefore to report on a larger series with a minimum of 2 years' follow-up in order to assess the effectiveness of such correction compared to other series.

Materials and methods

Between January 1993 and February 1996, 65 patients with right thoracic adolescent idiopathic scoliosis (excluding those with double thoracic, thoracolumbar or lumbar curves) underwent a posterior spine fusion using the AO Universal Spine System (Synthes USA, Paoli, Pa.). An independent observer (P.P.) reviewed hospital charts, operative reports, office notes clinical photographs and all radiographs. Of these, 41 cases met the following criteria: the primary curve was thoracic, only a posterior fusion was performed (without anterior release, thoracoplasty, or halo distraction), the

Fig. 2 **A** A 14-year-old girl with a progressive 63° right thoracic idiopathic scoliosis. **B** On convex side bending the curve corrects to 36°. **C** Concave side bending shows that the upper thoracic and the left lumbar curves are supple. **D** Two years after apical instrumentation with SPH and posterior spine fusion the correction is excellent, the Cobb angle is 17°, the apical vertebral translation is completely corrected and the lowest instrumented vertebra (L2) is parallel to the ground. **E** The lateral view shows satisfactory balance, one can see the 3.2-mm fixation screws in each instrumented pedicle of the apex

follow-up was at least 2 years, and the instrumentation had been done with SPH at the apex of the thoracic curve on the concave side (Fig. 2). The age of the patients ranged from 11 to 20 years (mean 14.5 years). There were 36 girls 5 boys.

Surgical technique

The following strategy was used for a right thoracic curve (Fig. 2). In the concavity, the apical most rigid segment as determined on convex side bending (at least three or four vertebrae including the apical vertebra) was instrumented with SPH. The convex side was instrumented with a SPH on the apical vertebra. The distal foundation was always achieved via two or more pedicle screws. Correction was achieved with either a segmental approximation of the apical vertebrae to a sagittally fixed concave rod, or rotation of the concave rod, or a combination of the two methods. The fusion was achieved through a decortication of the facets and laminae and iliac crest bone strips. Prophylactic antibiotics (cefazolin) were given at the time of anesthesia induction. The following parameters of deformities were studied: trunk shift (by the distance in millimeters between the C7 plumb line and the gluteal fold), shoulder elevation (by the offset between the two acromions determined by a spirit level), thoracic hump in millimeters, operative procedures, number of fused vertebrae, blood loss, postoperative complications. The preoperative radiographic evaluation included postero-anterior and lateral-standing radiographs of the spine with side-bending views. Postoperatively, radiographs were taken between the 5th and 7th day, at 6 weeks, at 6 and 12 months, and at the latest follow-up visit. All radiographs had the following data recorded: Cobb angle, apex of the curve, apical vertebral translation (as the distance between the middle of the apical vertebra and the mid-sacral line), and flexibility index of the curve (determined as the ratio between the Cobb angle of the curve minus the side-bending Cobb angle over the Cobb angle of the curve). The sagittal curves were measured taking into account the thoracic kyphosis between T4 and T12, and the lumbosacral lordosis between L1 and S1. No attempt was made to measure the rotation of the vertebrae.

Results

The average follow-up was 38 months (range 28–55 months). Analysis of the frontal plane correction showed the following (Table 1): Shoulder imbalance was corrected from a mean of 15 mm elevation (always right) (range 0–35 mm) preoperatively to 5 mm postoperatively

(right or left with a range of 0–25 mm), with nine patients having a postoperative left shoulder elevation. At the last follow-up, two patients had a persisting left shoulder elevation of 25 mm, the others patients being well balanced, within a 10-mm range). In the coronal plane 11 patients had a trunk shift superior to 15 mm preoperatively. At the last follow-up all patients (except two) were well balanced within 15 mm. One patient had a recurrent 20-mm trunk shift to the right occurring over 36 months; the other patient, who was balanced before surgery, had a left trunk shift of 15–20 mm at the last follow-up. At 1-year follow-up (Table 1), the rib hump was improved by 50% on average (30 mm of rib hump deformity on average corrected to 15 mm at 1-year follow-up). However, at the last follow-up, the rib hump had recurred to an average of 25 mm (17% correction). The angular correction was as follows: the mean thoracic Cobb angle was 55° (range 42°–80°) preoperatively, with a flexibility index of 46% (range 22–74%). The postoperative Cobb angle measured 18° on average (range 8°–20°). This represents a 67% correction. At the last follow-up, the Cobb angle was measured at 23° (58% correction). Apical vertebral translation was corrected to 80% postoperatively and 70% at the last follow-up, which corresponds to a preoperative value of 55 mm and a final value of 15 mm. The lumbar curve, whether instrumented or non-instrumented, corrected from 38° to 12° postoperatively and to 18° at the last follow-up. In the sagittal plane we observed no major differences between the pre- and postoperative values of the thoracic kyphosis and the lumbosacral lordosis (Table 1). The mean operative time was 300 min (range 210–420 min) for an average number of instrumented vertebrae of 10. Total blood loss on average was estimated at 1700 cc (range 600–3000 ccm) or 175 cc per operated level. No patient required homologous transfusion, because of the use of pre-donated autologous blood and the cell saver. Patients were mobilized on the 3rd postoperative day and were discharged from hospital on the 7th postoperative day on average (5–8 days). No braces were used postoperatively.

Table 1 Results of correction of 41 cases of adolescent idiopathic thoracic scoliosis with specialized pedicle hooks (AVT apical vertebral rotation)

	Preoperative	Postoperative	Last follow-up
Trunk shift	10 mm (0, 50)	1 mm (0, 15)	1 mm (0, 20) ^b
Shoulder imbalance	15 mm (0, 35)	5 mm (0, 25)	5 mm (0, 25) ^c
Rib hump	30 mm (10, 50)	15 mm (5, 35) (50%) ^a	25 mm (5, 45) (17%)
Cobb angle	55° (42°, 80°)	18° (8°, 35°) (67%)	23° (13°, 40°) (58%)
AVT	55 mm (17, 100)	10 mm (0, 30) (80%)	15 mm (0, 40) (70%)
Lumbar Cobb	38° (28°, 65°)	12° (0°, 25°)	18° (0°, 32°)
Thoracic kyphosis	23° (–10°, 46°)	22° (12°, 30°)	26° (14°, 45°)
Lumbosacral lord.	–53° (–45°, –75°)	–49° (–31°, –65°)	–59° (–40°, –74°)

^a Postoperative rib hump could only be measured at 1-year follow-up

^b Two patients were unbalanced by 15–20 mm at the last follow-up

^c Two patients had a left shoulder elevation of 25 mm

Complications

One patient complained of hypoesthesia in the T7-T8 dermatome on the left side over a 1-year period. Another patient complaining of urinary incontinence following the operation was diagnosed with a spastic bladder on urodynamic studies. A myelogram with CT was therefore done and was normal. The instrumentation was left in place and her symptoms completely resolved after 8 months. There was no modification of the instrumentation and no infection during our follow-up period, all fusions appeared solid. However, rods or cross links had to be removed in three patients because of pain or bursitis over the hooks. This was necessary at 18, 20 and 26 months.

Discussion

As the most rigid, translated and rotated part of the curve in AIS is the apex, it appeared logical to achieve a strong segmental instrumentation at this level. Previously this was achieved with instrumentations using sublaminar or interspinous wires [3, 10, 13, 19, 25]. In the Cotrel-Dubousset principles, the apical vertebra is not instrumented at all [8, 9]. Sublaminar wires or even conventional hooks do not assure a rigid fixation to the vertebra allowing rotation or gliding of the vertebra along the wires or rotation of the conventional hooks during correction maneuvers. The best vertebral fixation is well known to be achieved with pedicle screws. This has been used in the correction of AIS by Suk et al. [24] and Liljenqvist et al. [17], who documented better corrections in their pedicle screw groups than in their hook only groups. Both reported excellent correction using such techniques (72% of Cobb angle correction for Suk and 59% for Liljenqvist). However, this can only be used in experienced hands and the possible neurologic complications due to a misplaced pedicle screw must be kept in mind [20]. The small size, the rotation and the surgical anatomy of the pedicle at the thoracic level in AIS makes the insertion of pedicle screws even more difficult. The use of the pedicle hook as a guide for the drilling of a small 3.2-mm fixation screw makes the insertion of the SPH safer than conventional pedicle screws [1, 2]. By placing the SPH at the apex of the curve, we therefore achieved a strong segmental fixation which is close to the stability achieved with classic pedicle screws [5]. Another advantage SPH offer over classic hooks is that they will not displace during the correction maneuvers as they are solidly fixed to the vertebra. In this way they are less dangerous than conventional pedicle hooks which can displace in the canal during correction maneuvers. Furthermore, using such SPH there is no need to insert a laminar hook in the spinal canal. Neurologic complications related to the use of classic laminar hooks [4] lend support to this statement. As for a possible neurologic complication related to the medial breaching

of the pedicle wall by the fixation screw, we have not encountered any and no screws were deemed medial on the follow-up postero-anterior spine radiographs. CT scans were, however, not performed. When using such SPH there is no need either to distract the spine to load the hooks during correction. This is another advantage, as overdistraction has been thought to be responsible for decompensation [26]. We agree with Webb et al. [29] that the key is to let the spine autoelongate to its own length during the correction maneuvers, to avoid decompensation. Our Cobb angle correction was 67% postoperatively and 58% on average at the last follow-up. This compares favorably with the Liljenqvist series [17], where 59% of curve correction was achieved using mainly pedicle screws. It is known that one of the main factor that determines correctability is the flexibility of the curve [7]. This may account for a slight variation in the comparison of different series. However, our average Cobb angle compared favorably with most other series [3, 9, 15, 16, 21–24, 27, 28]. At our last follow-up, there was a slight deterioration (9% loss) of the Cobb angle, as has been noted in other series [16, 21]. Our small loss of Cobb angle correction (9%) did not occur in the instrumented spine, but above and below due to adding on that we observed during our follow-up period, as we always measure the overall Cobb angle of the curvature irrespective of the fusion block. This adding on was observed in the fusions that were too short. Apical vertebral translation was corrected by 70% on average, which is higher than the 60% reported by Lenke and Bridwell [16] in their series on the CD instrumentation. With regard to the sagittal plane, we obtained results similar to the meta-analysis of Stasikelis et al. [23]. The thoracic kyphosis correction was not fully recreated, and we now remove the ligamentum flavum in selected cases of thoracic hypokyphosis (which we have not done in this series). Rotation was not studied in this series, as we think only CT can give an adequate measurement. However, we studied the rib hump, which is related to the rotation of the spine and the deformation of the rib: At the last follow up the correction of the rib hump deformity was minimal (17%). This implies that only minimal derotation was achieved, as in other series [11].

Complications

The major complication of the series was a spastic bladder after correction of an 80° curve to a 20° curve in a patient with a spina bifida occulta at T12. As all the implants were all properly positioned on the CT myelogram, we could only blame either a possible injury to the conus during the surgery (yet not recognized) or a possible overstretching of the spinal cord. The preoperative MRI that had been done in view of the spina bifida occulta at T12 was perfectly normal.

Decompensation

Two patients had at the last follow-up a high riding left shoulder of 25 mm. This can be explained by a too excessive correction of the main right thoracic curve with a higher left rigid thoracic curve that should have been instrumented retrospectively. In the coronal plane two patients were imbalanced at the last follow-up. One of them was fused short of the safe zone and reverted to his initial trunk shift over 36 months. For the other one the lumbar curve did not respond as anticipated and she remained imbalanced to the left. We have three patients who required rod or cross link removal because of pain over prominent hardware between the two scapulae. This did not affect the final result, but consideration for lower profile instrumentation is currently given for thin patients. When comparing our results to our previously published series [1] of only 20 patients with a short-term follow-up, we obtained

similar results on the different parameters of curve correction. The rib hump deformity, however, increased further with longer follow-up.

Conclusion

The use of an apical instrumentation on the concave side of the spine with SPH is effective in correcting thoracic scoliosis in AIS. This new segmental instrumentation addresses the most rigid and deformed part of the scoliosis, and does not require any distraction and implant in the spinal canal. No neurologic complication related to their use was observed in this series of 41 patients.

Acknowledgements We acknowledge the assistance of Mark Lepik from the Shriners Hospital for the illustrations.

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