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Posterior only surgical correction of severe adolescent idiopathic scoliosis > 70º using high density pedicle screws

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Abstract
Type of study: Prospective cohort study**.**
Objective: To evaluate the safety and effectiveness of high density pedicle screws through posterior only approach in correction of severe cases of adolescent idiopathic scoliosis (AIS) with curves > 70º.
Material and methods: Between 2012 and 2014, fourteen patients were surgically treated for severe AIS with curves > 70º and were prospectively followed up for a minimum of 1 year (range 1-4 years). Clinical outcomes were evaluated using SRS-22 questionnaire. All patients were classified according to Lenke *et al* classification. Major and minor curves Cobb angle as well as sagittal parameters were measured on whole spine X-rays. Side bending films were used to assess curve flexibility. High density pedicle screws and multiple Ponte osteotomies were used in all patients. Five patients required asymmetrical pedicle subtraction osteotomy due to very rigid curve.
Results: This study included 14 patients (8 females, 6 males).The mean age at time of surgery was 17.4 years (range 14-24 years). The mean correction rate for the coronal Cobb angle of the major and minor curves was 73.7% (80.4º preoperative and 21.7º postoperative) and 68.7% (51.5º preoperative and 19.63º postoperative) respectively. The mean thoracic kyphosis angle was 44.2º preoperatively, 28.55º postoperatively and 28.1º at latest follow up. The mean SRS-22 questionnaire scores improved significantly from 2.8 preoperatively to 3.7 at the final follow up ($p < 0.001$). No cases of pseudarthrosis, metal failure or neurological deficits were encountered. One patient with asymmetrical PSO developed hemothorax that was managed with chest tube insertion and follow up.
Conclusion: High density pedicle screws through posterior only approach is a safe and effective method in treatment of severe AIS. It can achieve coronal curve correction comparable to combined anterior and posterior approaches without the morbidity of combined approaches. It also restores the sagittal profile leading to good functional outcomes and better quality of life.

Keywords: High density pedicle screws, severe idiopathic scoliosis, posterior approach, Adolescent spine deformity.

Introduction

The classic treatment of severe rigid adolescent idiopathic scoliosis (AIS) was performed by an anterior release with an open thoracotomy followed by posterior instrumented fusion [1]. The combined anterior and posterior procedure can be performed in one or two stage surgery with or without halo traction in-between [2, 3]. Additional anterior surgery requires increased time for the general anesthesia and may have a negative impact on pulmonary function, longer hospital stay, more blood loss and longer operative time [4].

Video assisted thoracoscopic surgery (VATS), used for the anterior release, followed by posterior instrumentation have been also used for severe rigid AIS [5, 6]. However, it can minimize, but not eliminate, the negative effect on the pulmonary function, as reported by Newton *et al* [7].

Pedicle screws, by allowing secure segmental three-column fixation through the familiar posterior approach, have become the principle method for scoliosis correction with many advantages over other fixation method [8].

The aim of this study was to evaluate the efficacy and safety of using high density pedicle screws through posterior only approach to correct severe cases of AIS with curves > 70º.

Patients and Methods

Between 2012 and 2014, fourteen patients with severe AIS were treated surgically and were prospectively followed up for a minimum of 1 year. This study was approved by our institution ethical committee and an informed consent was taken from every patient.

All patients with AIS older than 10 years of age with curves more than 70º were included. Patients with non-idiopathic curves, previous surgery, patients younger than 10 years old as well as those with moderate curves (less than 70º) were excluded.

After complete medical history and careful physical/neurological examinations, all patients had preoperative whole spine anteroposterior (AP) including the shoulders and the pelvis and lateral films. Side bending films were obtained for all patients to assess curve flexibility.

In the AP view, Cobb angle [9] of the major curves as well as the minor curves was measured. Global coronal balance was measured as the distance between the C7 plumb line and the central sacral vertical line (CSVL). In the lateral view, thoracic kyphosis was measured from the upper end plate of D5 to the lower end plate of D12 and lumbar lordosis was measured from the upper end plate of L1 to the upper end plate of S1. Global sagittal balance was assessed from the distance between C7 plumb line and the posterosuperior corner of S1 in millimeters with positive values in front and negative values behind the posterosuperior corner of S1. In the side bending films Cobb angle of the major and minor curves was measured to assess flexibility of the curves [10].

All patients were classified according to the Lenke *et al*. classification [11] into one of the six main types. Lumbar and thoracic sagittal modifiers were determined for every patient and only structural curves were fused.

The upper instrumented vertebra was D4 if the patient had high right shoulder, D3 if the patient had balanced shoulders and D2 if the left shoulder is high. The Lower instrumented vertebra was the end vertebra if it was touched by the CSVL and End+1 or End+2 if the end vertebra was not touched by CSVL.

Surgical technique

All patients were operated in prone position on a transparent surgical table under general anesthesia. High density pedicle screws were inserted across the instrumented levels using the free hand technique. Extended head screws were used as a routine on concave side to assist in apical reduction. After finishing pedicle screws insertion, their optimal position was checked using intraoperative fluoroscopy both in AP and lateral views. Multiple Ponte osteotomies were routinely done to improve curve flexibility. Asymmetrical pedicle subtraction osteotomy (PSO) was done in selected cases with very rigid curve. Concave rod was inserted first and then derotation of the spine was done by rod derotation technique. Insertion of the convex rod and final segmental compression and distraction was used to improve correction.

The wake-up test was used in every patient to ensure neural integrity. Posterior spinal arthrodesis was then done using autologous local bone graft. In this series, no iliac bone graft was used, no local antibiotics were added to the bone graft. Finally, the wound was closed in layers over a suction drain.

All patients were mobilized as early as tolerated without any external support. Post-operative radiograph was taken shortly after surgery and patients were followed up at 2 months, 6 months, 1 year and 2 years after surgery. The preoperative radiological parameters were re-measured shorty after surgery and at each follow up radiograph. Functional outcome was assessed using the SRS-22 questionnaire. Statistical analysis was done using the SPSS program (IBM SPSS version 20.0) using chi-square and t-test. P value less than 0.05 is considered statistically significant.

Results

This study included 14 patients, 8 females and 6 males. The mean age at surgery was 17.4 years (range 14-24 years). The mean follow up period was 19.6 months (range 12-44 months). The mean operative time was 354 minutes (range 280 to 440 minutes) with mean blood loss of 1400 cc (range 700 to 1900 cc) and average 4 units (range 3 to 6 units) of blood transfusion were needed. The average number of fusion levels was 15.4 levels with a mean of 23.4 pedicle screws inserted per patient with total 328 screws inserted in 215 levels. Multiple Ponte osteotomies were done in every patient while asymmetrical PSO was done in 5 patients.

The most common curve type was type 3 in 6 patients followed by type 1 in 5 patients *(figure 1)*. Thoracic kyphosis was normal in 5 patients (Sagittal modifier N), hypokyphosis in 1 patients (Sagittal modifier -) and hyperkyphosis *(figure 2)* in 8 patients (Sagittal modifier +).

The mean preoperative Cobb angle of the major curve was 80.4º with a mean of 19.7% curve flexibility *(figure 3)*. This had been corrected to 21.07º postoperative (P<0.001) and to 22.2º at latest follow up. The percent of curve correction was 73.7% with 1.9% loss of correction at latest follow up (p= 0.796).

The mean cobb angle of the minor curve was 51.5º preoperative *(figure 3)*, that has been corrected to a mean of 19.4º postoperative (p<0.001) and was 20.86º at latest follow up with 68.7% percentage correction of the minor curve and 2.4% percentage loss of correction at latest follow up (p=0.436). The mean global coronal balance was 2.89 cm preoperatively, 1.76 cm postoperatively (p=0.047) and 0.9 cm at latest follow up (p=0.112).

The mean preoperative thoracic kyphosis *(figure 4)* was 44.2º and was 28.5º postoperatively (p=0.003). At the latest follow up the mean thoracic kyphosis was 28.1º (p=0.789). The mean lumbar lordosis was 50.1º preoperatively, 41.0º postoperatively (p=0.016) and 42.2º at latest follow up (p=0.865). The mean global sagittal balance was -25 mm preoperatively and +37 mm (p=0.971) postoperatively and +26 mm at latest follow up (p=0.688).

The SRS 22 questionnaire improved significantly from a mean of 2.8 preoperative to 3.7 at latest follow up (p <0.001). Both the total score and the 5 domains scores improved after surgery.

In this series, there were no cases with neurological deficits post-operatively. No metal failure or pseudarthrosis was detected during the follow up period. One patient with asymmetrical PSO developed hemothorax postoperatively that was managed with chest tube insertion for 24 hours.

Discussion

In recent years, posterior only surgery using all pedicle screws has been used for treatment of severe AIS and has resulted in similar correction rate to the combined anterior/posterior approach with much less morbidity than the combined approaches [12-14].

In this prospective cohort study, we have achieved 73.7% coronal correction of the major curve which is better than previous studies using posterior only approach for severe AIS which ranged from 52% to 68% [1, 14-19]. We think that increasing implant density as well as using extended head reduction screws on concave side in our patients offered an efficient derotation maneuver and this may have resulted in better curve correction. Also, the routine Ponte osteotomies in all patients and asymmetrical PSO in very rigid curves improved curve correction and may also explain the better coronal correction in this study.

Regarding the sagittal profile, the mean final thoracic kyphosis in this series is 28.7º and the mean lumbar lordosis is 42.2º. This falls within the normal range of thoracic kyphosis and lumbar lordosis and indicates the ability of all pedicle screws through posterior approach to keep sagittal parameters.

Dobbs *et al*. found similar correction rate between combined anterior/posterior fusion and posterior only fusion in curves exceeding 90° with less negative effect on pulmonary function in posterior only group [12].

Luhmann *et al* also concluded that correction achieved by posterior pedicle screws only is similar to combined approach in severe curves (70-100) ° and avoided the negative effect of anterior release on pulmonary function [13]. Similar results came from Kuklo *et al*. in curves more than 90° [14]. These studies concluded that isolated posterior correction with pedicle screws can result in satisfactory correction without the morbidity of anterior release and motivated many authors to state that

anterior release is no longer mandatory in severe rigid curves of AIS.

The posterior approach for scoliosis correction is a simple exposure, familiar to all surgeons, with little risk for major vascular injury and with good control of the coronal and sagittal plane of the spine. Also, it preserves the pulmonary function as the chest cage is not violated under normal circumstances [20].

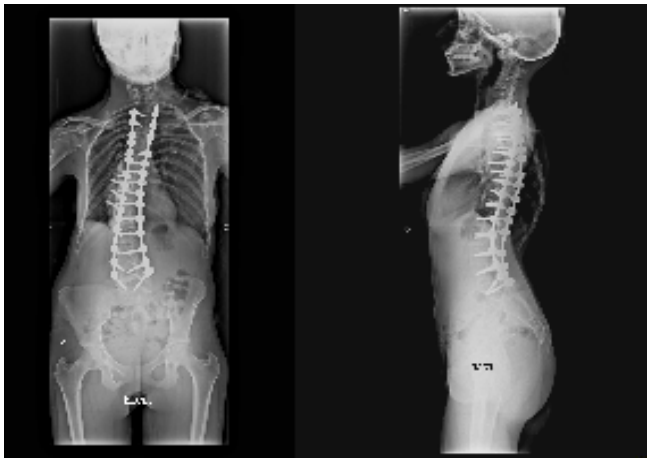
Pedicle screws related complications can result from initial malposition of the screws or due to screws pull out during deformity correction resulting in neurological, vascular or visceral injury as well as loss of correction in the postoperative period. Despite the high rate of screw misplacement that can reach up to (15.7%) in some studies [21], the incidence of major complication requiring revision surgery is very low [22, 23] and ave been reported as single case reports [24]. Several techniques have been used to guarantee safety of thoracic pedicle screws. These include the anatomical free hand technique [25] as well as the open lamina technique [26] with direct visualization of the medial wall of the pedicle. In this series we used the free hand anatomical technique and we have no screws related major complication that required revision surgery out of 328 screws used.

In 2015, Chen and Rong published a meta-analysis comparing combined anterior–posterior approach versus posterior-only approach in treating AIS. They concluded that posterior-only approach can achieve similar coronal plane correction compared to combined anterior–posterior approach with better sagittal correction in severe AIS patients. They reported significantly less complication rate, blood loss, operative time, length of hospital stay and better percent-predicted FVC by posterior-only approach [4].

In conclusion, high density pedicle screws technique through posterior only approach is an effective and safe method for treatment of severe AIS. It alleviates the need for anterior surgery and eliminates combined approaches related morbidity. It can achieve similar curve correction with minimal loss of correction. It also restores the sagittal parameters within normal range leading to better sagittal balance. The screw related complications are minimal and major complications rarely occur. As the incidence of severe AIS is relatively uncommon, we recommend performing this study as a multicenter study to include large number of patients with longer follow up periods.

Case 1

A



B

Fig 1: Male patient 16 years old with Lenke 1 c n.
A) Preoperative X-rays showing main thoracic curve of 85º that had been corrected to 80º in side bending films with thoracic kyphosis of 40º.
B) Two years postoperative showing posterior instrumentation from D3-L5 with main thoracic curve correction to 22º with thoracic kyphosis of 28º.

Case 2

A

B

Fig 2: Male patient 18 years old with Lenke 4 a +.
A) Preoperative X-rays showing main thoracic curve of 105º with thoracic kyphosis of 52º.
B) One and half years postoperative showing posterior fusion from D2-L4 with main thoracic curve correction to 44º with thoracic kyphosis of 32º.

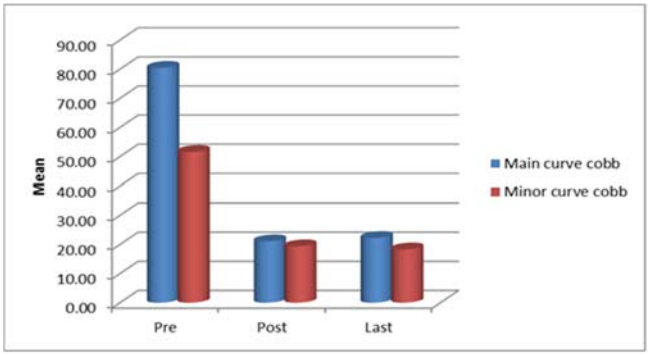


Fig 3: Coronal parameters

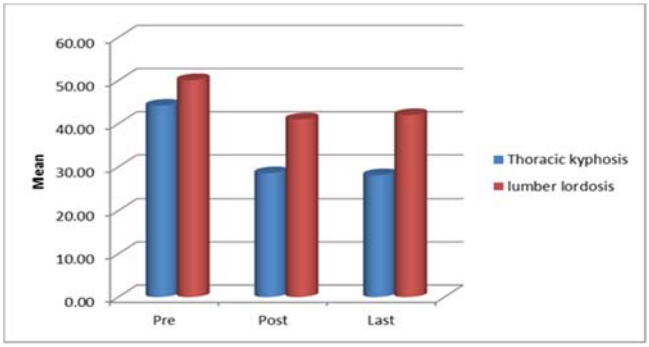


Fig 4: Sagittal parameters.

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