Three-Planar Surgical Correction of Adolescent Idiopathic Scoliosis

Abstract

Introduction: Various methods for achieving vertebral body rotation for rib hump reduction have been described overtime for adolescent idiopathic scoliosis, but no paper has previously described a combination of segmental and en block rotation. In this paper we describe the combination of these two techniques.

Materials and methods: Retrospective study, describing the results of scoliosis surgical correction with segmental and en block direct vertebral rotation, regarding 38 adolescent patients affected by idiopathic scoliosis. Mean follow up was 27 months (min 12 months, max 34 months). Radiographic evaluation was performed by measuring main curves Cobb angle as well as apical vertebral body rotation before and after rotation maneuvers. Clinical results were assessed by evaluating pre-operative and final follow up rib hump with scoliometer.

Results: Main curve was corrected from a mean 65.6° (min. 40, max 80°) to a mean 17.4° (min 5°, max 28°). Apical vertebral body rotation before corrective maneuvers was: 73.7% grade 2, 22.2% grade 1, 4.1% grade 0. Apical vertebral body rotation at final correction was: 10.4% grade 2, 44.5% grade 1, 45.1% grade 0. All differences were statistically significant.

Conclusion: The described technique is efficient in correcting idiopathic scoliosis and most of all reducing rib hump.

Introduction

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity, with spinal column deviation towards the right or left side in the coronal plane, thoracic kyphosis alteration in the sagittal plane (most frequently hypokyphosis) and vertebral rotation in the axial plane that is responsible for the rib hump. Amongst various techniques for surgical treatment of adolescent idiopathic scoliosis, pedicle screws are the only constructs that allow to deliver corrective forces throughout the entire length of the vertebral body of each instrumented vertebra, as opposed to instrumentations that have a posterior arch purchase only such as hooks or laminar wires/bands. Pedicle screws allow to perform complex corrective procedures providing scoliosis correction not only in the coronal plane but also rib hump reduction in the axial plane thanks to Direct Vertebral Body Rotation (DVBR). DVBR may be achieved by Segmental Vertebral Rotation (SVR, rotation of adjacent vertebral segments sequentially) or En-Block Vertebral Rotation (EVR, rotation of a group of vertebra at the apex of scoliosis). Each of these rotational techniques has been previously singularly described with satisfactory results. We present results with a newly described surgical technique that combines both SVR and EVR.
Materials and Methods

AIS patients who received surgical treatment from 2012 to 2016 were retrospectively reviewed, with the following inclusion criteria: age from 12 to 18 years, major curve between 40° and 80°, surgical treatment by posterior approach with exclusively pedicle screw instrumentation and 5.5 mm Cobalt-chrome rods, screw density superior to 90% and at least 1 pedicle screw per level, no thoracoplasty, minimum follow up of 1 year. All types of curves according to the Lenke classification were included.

Radiographic parameters were measured on upright posteroanterior and lateral radiographs preoperatively and at the final follow up. Scoliosis correction was measured on pre and post-operative standing x-rays, apical vertebral derotation was measured upon intraoperative fluoroscopy by confronting post-pedicle screw placement imaging and final correction imaging according to a modified Upasani method [1]: we compared intraoperative fluoroscopy images of major curve’s apical vertebra after screw insertion and at final correction, grading vertebral body rotation rotation from 0 to 2, based on convex screw tip location (Figure 1).

Clinical results were measured using standard rib hump inclinometer. Quality of life was evaluated with the Scoliosis Research Society questionnaires (SRS-22), covering five domains including function/activity, pain, self-perceived image, satisfaction with treatment and mental health, completed by all patients at final follow up.

Statistically significant differences were evaluated with Student’s T test with a P value inferior to 0.05 being considered as statistically significant.

Surgical Technique

The levels of instrumentation were defined according to the Lenke classification criteria, limiting fusion to structured curves only in order to preserve as many mobile spinal segments as possible. Posterior exposure of the spine and pedicle screw placement was performed, with screw density superior to 90% and at least 1 pedicle screw per level in order to be able to manipulate each single vertebra (Figure 2). Screw diameter was 6.5 mm at all instrumented levels. In all cases, uniplanar screws are used at the apex of each instrumented curve (where DVBR maneuvers take place), multiaxial screws were used only at the extremities of the instrumentation. Pedicle screws were placed by free hand searching technique followed by fluoroscopy intraoperative images. Facetectomies were performed at all treated levels, Ponte osteotomies were performed at least at 4 apical levels.

Once all pedicle screws are placed, derotation extensors are placed at every screw head bilaterally. SVR maneuvers begin from distally to proximally without any rods in place; once SD has reached the desired torsion between two adjacent vertebrae, the extensors of those specific segments are fixed and SD may progressively proceed to the next level. Once sequential SD has reached the most proximal thoracic levels covering all rotated segments, the extensors of the first rod side are removed (Figure 2).
First rod was always placed on the left side for major thoracic curves (Lenke 1 to 4 types) and at the right side for major lumbar curves (Lenke 5 and 6 types). Rods were contoured in a differential manner with hyperkyphotic thoracic concave rod and hypokyphotic thoracic convex rod.

First rod placement is obtained progressively by using multilevel screw reduction tools. When the rod is reduced into the screw heads, a Cotrel-Dubousset simple rod rotation is performed while performing EVR on the ipsilateral side upon extensors already blocked in SD between each other (Figure 3). This way, SD is performed without rods and ED is performed during first rod reduction, thus maximizing DVBR effect.

**Figure 2**: Direct vertebral body rotation technique: a: segmental rotation without rods by torqueing one level to another sequentially, b: en-bloc rotation with only 1 rod: while the first rod is being reduced (upper side of the image) the extensors are being pushed down for obtaining further vertebral body rotation.

**Figure 3**: Clinical and radiographic results, Lenke 1 scoliosis (right thoracic curve).

T3-L1 posterior fusion, with satisfactory three plane correction: curve correction in the frontal plane, rib hump reduction in the axial plane and thoracic kyphosis restoration in the sagittal plane.
Once rod rotation and EVR have reached the desired position, the first rod is tightly fixed. At this point, remaining extensors are removed and second rod is placed from proximal to distal in a Cantilever fashion in order to enhance rib hump reduction. Surgical procedure is then concluded by second rod tightening followed by bone graft and wound closure.

Results

38 consecutive patients were identified, respecting the aforementioned inclusive criteria of whom 29 were female and 9 were male. Mean age was 14.3 years (min 12, max 18). Mean follow up was 27 months (min 12 months, max 34 months).

Main curve was corrected from a mean 65.6° (min. 40, max 80°) to a mean 17.4° (min 5°, max 28°). Apical vertebral rotation improvement was statistically significant. Apical vertebral body rotation before corrective maneuvers was: 73.7% grade 2, 22.2% grade 1, 4.1% grade 0. Apical vertebral body rotation at final correction was: 10.4% grade 2, 44.5% grade 1, 45.1% grade 0 (Figure 1).

There was statistically significant improvement in sagittal thoracic kyphosis, in hypokyphotic patients (T4-T12 inferior to 10° before surgery) passing from a mean 3.6 pre-op to a mean 23.2 post-op. No statistically significant improvement was noted in patients with normal pre-operative kyphosis (T4-T12 between 10° and 40°). Clinically, rib hump improved significantly from a mean 12.9° (min. 10°, max 19°) to a mean 3.7° (min 0°, max 6°) at final follow up (Figures 3 and 4).

Discussion

Scoliosis surgical correction has undergone significant evolution throughout the past 50 years, passing from simple distraction with Harrington rod followed by body cast for several months to complex techniques that allow for vertebral column manipulation and immediate ambulation with no need for post-operative cast or brace. The advent of pedicle screws has allowed for solid multi-level purchase of the spine capable of delivering significant corrective forces to the scoliotic deformity, both in coronal, sagittal and axial plane [1]. In particular, axial plane correction is achieved thanks to rotating maneuvers that are carried out by extensors attached to pedicle screw heads. There are mainly two types of direct vertebral body rotation, either by using a group of extensors at the apex of the deformity (en-block rotation) or by rotating each level at a time (segmental rotation) [2-7]. In this study we describe in a detailed manner a unique technique that combines both these procedures. We believe that in order to maximize derotation effect, spinal column must be as less constricted as possible. Hwang et al., [4] described satisfactory results with SD, ED or both, describing SD and ED separately but without clarifying how they combined SD and EB together; presumably SD was performed with convex rod already in place and ED with both rods in place which may limit derotation potential because of difficulty to manipulate spinal rotation due to rods restriction. Performing SD without any rods and therefore upon an unrestricted spine is the main advantage of our technique. The other advantage is that ED is performed to an already segmentally derotated spine and with only one rod placed. No derotation maneuvers are performed with both rods in place, therefore, vertebral derotation results were satisfactory.

Previous reports state that DVBR may have a hypokyphotic effect on thoracic spine [5,6]. Differential rod contour has successfully addressed this argument, by providing a hyperkyphotic effect thanks to concave stiff rod contoured in hyperkyphosis [7]. Our technique of combined DVBR
is compatible with differential rod contouring for enhanced overall thoracic kyphosis restoration and rib hump reduction. In fact, differential rod contour and exclusively cobalt chrome rods were applied in all patients.

DVBR corrections were performed upon uniplanar or monoaxial screws in all cases for better vertebral derotation [8]. In conclusion, the described surgical technique of combined SD and EBD can enhance overall DVBR and therefore provide satisfactory axial derotation and overall adolescent idiopathic scoliosis correction. Our technique it is compatible with differential rod contour and may be applied in all types of adolescent idiopathic curves.

References


