Clinical Study

Posterior all-pedicle screw instrumentation combined with multiple chevron and concave rib osteotomies in the treatment of adolescent congenital kyphoscoliosis

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Received 18 April 2011; revised 18 April 2012; accepted 13 October 2012

Abstract

BACKGROUND CONTEXT: Congenital kyphoscoliosis is a disorder that often requires surgical treatment. Although many methods of surgical treatment exist, posterior-only vertebral column resection with instrumentation and fusion seem to have become the gold standard for very severe and very rigid curves. Multiple chevron and concave rib osteotomies have been previously reported to be effective in the treatment of neglected severe idiopathic curves. We hypothesized that this method may also be used successfully in the treatment of congenital kyphoscoliosis.

PURPOSE: To evaluate the effectiveness and safety of multiple chevron osteotomies combined with concave rib osteotomy and posterior pedicle screw instrumentation.

STUDY DESIGN: Retrospective chart review in the spine service of a large university hospital.

PATIENT SAMPLE: Adolescent patients undergoing a specific surgical treatment for the indication of rigid congenital kyphoscoliotic deformity.

OUTCOME MEASURES: Radiographic images were used for the measurement of deformity correction. The Turkish version of the Scoliosis Research Society 22 (SRS-22) Patient Questionnaire has been used as a clinical outcome measure in the patient population.

METHODS: A retrospective chart review was performed. Patients admitted to Hacettepe Hospital Spine Center during the period of 2005 to 2009 were included. Criteria for inclusion were as follows: adolescent age group (10–16 years); congenital kyphoscoliosis; formation and/or segmentation defect of at least two vertebral motion segments; surgical treatment of deformity by posterior all-pedicle screw instrumentation, multiple chevron osteotomies, and multiple concave rib osteotomies; follow-up of at least 24 months; and a complete set of preoperative, postoperative, and follow-up standing posteroanterior and lateral full spinal radiographs. The patients’ hospital records and X-rays were reviewed. Duration of surgery, intraoperative blood loss, postoperative transfusion requirements, postoperative stay in postanesthesia care unit (PACU), time of hospitalization, and complications were recorded. Deformity in both coronal and sagittal planes was analyzed for correction and maintenance of the correction in preoperative, postoperative, and follow-up radiographs. Patients’ health-related quality of life was assessed using the SRS-22 questionnaire at the final follow-up.

RESULTS: Eighteen patients met the inclusion criteria. Their average age was 13.6 years (range, 11–16 years). Chevron osteotomies were performed at apical segments (three to seven levels) and...
Introduction

The surgical treatment of rigid congenital kyphoscoliotic curves of a complex nature has come a long way in the past decade. In the past, the treatment of these difficult deformities has been based on separate anterior and posterior approaches, performed simultaneously, sequentially, or in a staged manner [1–5]. Classically, during the first phase, anterior releases and discectomies are performed to achieve flexibility. Then, through the posterior approach, in situ or instrumented fusion is carried out. Although the effectiveness of and the correction rates achieved through this mode of treatment remain undisputed, long combined surgical times, significant amounts of intraoperative bleeding, and serious postoperative morbidity have given rise to the search for alternate methods [6–8]. In addition to general problems related to two-stage surgery, total discectomy and the achievement of good flexibility are often impossible because of the inherent problems related to the segmentation and fusion anomalies related to congenital deformities. Although effective anterior discectomy can be performed in congenital kyphosis, the fact that the posterior column is not shortened during posterior surgery puts the cord at significant risk when the anterior column of the kyphotic segment is relatively lengthened.

Posterior-only approaches for the correction of severe spinal deformities have become popular in the last years [1–3,6,9–16]. With the advent of multisegmental three-column fixation that pedicle screws provide and increasingly improved technique regarding posterior osteotomies, almost any severe deformity can be addressed through a posterior-only approach, negating the morbidities associated with an anterior procedure while not compromising the effectiveness of correction that would otherwise have been achieved through a combined approach and circumferential arthrodesis [17]. The shortening of the posterior column with posterior osteotomies will prevent iatrogenic distraction of the spinal cord as well. Among these, posterior vertebral column resection (PVCR) has been promoted as the best, and sometimes only feasible option, in the correction of very severe and very rigid complex congenital curves.

Multiple chevron osteotomies combined with concave rib osteotomies and posterior pedicle screw instrumentation have been reported to be effective in the treatment of neglected severe idiopathic curves [18–22]. When combined with posterior pedicle screw instrumentation, this technique can provide flexibility in rigid curves and a significant amount of correction. However, there are no reports in the literature regarding the application of this technique to rigid congenital curves with a kyphotic component. It was the aim of this study to evaluate the safety and effectiveness of posterior all-pedicle screw instrumentation and multiple chevron osteotomies combined with concave rib osteotomies in complex congenital kyphoscoliosis to establish its presence as an option in the treatment of these severe rigid curves.

Patients and methods

After obtainment of approval from Hacettepe University Institutional Review Board, a retrospective chart review was performed. Patients admitted to Hacettepe Hospital Spine Center during the period of 2005 to 2009 were included.

Criteria for inclusion included adolescent age group (10–16 years) with a diagnosis of congenital kyphoscoliosis, which was defined as a defect of formation and/or segmentation of at least two vertebral motion segments. All patients who underwent surgical treatment by posterior

Keywords: Congenital; Kyphoscoliosis; Pedicle screw instrumentation; Chevron; Osteotomy
all-pedicle screw instrumentation, multiple chevron osteotomies, and multiple concave rib osteotomies were followed for at least 24 months and had a complete set of preoperative, postoperative, and follow-up standing posteroanterior and lateral full spinal radiographs.

The patients’ hospital records and X-rays were reviewed. Duration of surgery, intraoperative blood loss, postoperative transfusion requirements, postoperative stay in postanesthesia care unit (PACU), time of hospitalization, and complications were recorded. Deformity correction and maintenance of the correction were evaluated by measurement in preoperative, postoperative, and follow-up radiographs. Major and compensatory scoliotic curves were measured using the Cobb method. Kyphosis was evaluated both globally (T2–T12) and locally (between the upper and lower levels of deformity). Patients’ health-related quality of life was assessed using the Scoliosis Research Society 22 (SRS-22) Patient Questionnaire at the final follow-up. The Turkish version of the SRS-22 questionnaire has previously been validated in a published study [23].

**Surgical technique**

All procedures are performed by two senior spinal surgeons (MY and AA). After relevant medical preparation, including magnetic resonance imaging scans for intraspinal pathology and 3-dimensional computed tomography for appropriate preoperative planning, patients are brought to the operating suite where traction anteroposterior X-rays are obtained after the induction of anesthesia. All scoliotic curves were measured again on this traction X-ray to quantify the flexibility of the curve. The end levels of instrumentation in the coronal plane are chosen on this X-ray: The lowest upper and highest lower vertebra with less than Grade I rotation according to Nash-Moe scoring are used. In the sagittal plane, this must correspond to a level at least three levels above and below the apex of kyphosis. If criteria for kyphosis and scoliosis did not match, the criteria that were appropriate for kyphosis were used.

All surgeries were performed using a posterior-only standard midline approach under transcranial electric motor evoked potential monitoring. Subperiosteal dissection down to the bone is performed to the extent of exposing transverse processes bilaterally. After exposure is complete, pedicle screw instrumentation is performed using the freehand technique as described before in the literature, and screw positions are checked with intraoperative image intensification afterward. Malpositioned screws, if present, are corrected at this stage. At the apex of the coronal curve, reduction screws are used. After the completion of instrumentation, chevron osteotomies are performed. First, posterior ligaments consisting of supraspinous and interspinous ligaments are removed. Facet capsules are opened and facetectomy as described by Moe is performed to assist with flexibility for deformity correction during surgery and later fusion. The facetectomy is kept wide to avoid nerve root impingement after correction, especially at the convex side. In unfused segments, the ligamentum flavum is removed, after which the intersegmental space between levels is increased in a chevron shape as previously described (Fig. 1). In congenitally fused segments, the intertransverse line is used as a landmark to create new interlaminar spaces.

Concave rib osteotomy is carried out routinely on vertebral segments contributing to the thoracic level deformity Cobb-to-Cobb by extending exposure past the transverse process to achieve 2 to 3 cm of careful subperiosteal dissection of the ribs on the concave side of the deformity. A rib cutter is then used to section the rib approximately 1 cm lateral to the transverse process. A chest tube is not inserted routinely but air leaks checked for by filling of the area with saline after the completion of osteotomy and positive-pressure ventilation. If the convex rib hump is too obvious after the procedure, convex rib osteotomy was performed in a similar technique. In this cohort, only one patient required this procedure. If no leaks are found at this time, an anteroposterior chest X-ray is made before the patient leaves the operating theater postoperatively.

After osteotomies are performed, physiologically precontoured rods are inserted into the present instrumentation and correction performed with the employment of translation and in situ bending maneuvers. Fusion is obtained by decortication of instrumented segments and the addition of allograft. At least one negative-pressure drain below the fascia is put in and kept in place for 24 to 48 hours postoperatively. Postoperative antibiotics are used for 24 hours.

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**EVIDENCE & METHODS**

**Context**
Congenital kyphoscoliosis presenting for surgical treatment at adolescence can present significant technical challenges.

**Contribution**
The authors found that they were able to achieve moderate correction using a posterior-only approach via chevron and rib osteotomies in a well-defined subgroup of patients with congenital kyphoscoliosis.

**Implications**
While this is a small retrospective case series, it presents outcomes in a well-defined clinical subgroup using a well-defined surgical technique and measured with an accepted and validated outcome instrument. For uncommon clinical problems, a study such as this is often the best available evidence.
Postoperative course

Patients are brought to PACU for a minimum overnight stay and, after 24 hours, mobilized. Patients are discharged from PACU as soon as their medical condition permits and brought to their regular beds in the orthopedic surgery ward. Postoperative upright X-rays are obtained 48 to 72 hours after surgery. No form of external immobilization is used. If no complications occur, the patient is discharged from the hospital if his or her condition permits, usually at Postoperative day 4 or 5. The patient is asked for a return visit, and follow-up X-rays are obtained at 6 weeks, again at 3 months, and yearly after that if no unexpected events occur.

Data collection and analysis

Data collection was performed retrospectively by review of patients’ medical charts, operating room notes, surgical records, and X-rays by the authors. X-ray measurements were performed by the authors on dedicated computer software (Centricity PACS-W version 3.7.3.4007; General Electric, Milwauk ee, WI, USA). Outcome analysis was performed by the physician evaluating the patients at follow-up during a face-to-face interview conducted after the visit. Statistical analysis was performed using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA).

Results

A total of 103 adolescent patients with the diagnosis of congenital spine deformity were found to have been operated on in Hacettepe Spine Service during that period. Rigid congenital curves that did not have an excessively kyphotic component were excluded. Of these, 18 patients met the inclusion criteria, 11 of which were male and 7 were female. The average age of the patients was 13.6 years (range, 11–16 years). All patients were diagnosed with congenital kyphoscoliosis at initial visit. Six patients had received treatment previously (two had undergone in situ fusion in a different center and whose increase in deformity was the indication for surgery and four had undergone neurosurgical spur excision for diastematomyelia). No patient had known pulmonary or cardiac comorbidities at presentation. None had any preoperative neurologic deficit. All patients were followed for a minimum of 24 months and an average of 34.3 months. The demographic data of the patients included in the study can be found in Table 1. Radiographic and clinical appearance of two of the patients can be seen in Figs. 2 and 3.

The average preoperative measured scoliosis was 66.0° (range, 31°–116°), which was corrected to 52.4° (range, 22°–85°) on traction X-ray taken under anesthesia and was found to have been corrected to 24.9° (range, 12°–52°) postoperatively, with a correction rate of 62%. The average scoliosis of the patients at follow-up was 27.5° (range, 10°–50°). The preoperative global kyphosis (T2–T12) of 75.9° (range, 50°–106°) was corrected to 49.5° (range, 18°–66°). At follow-up, the global kyphosis was found to be 50.3° (range, 28°–73°). The average local kyphosis was 71.9° (range, 35°–114°) preoperatively, which was found to have been corrected to 31.4° (range, −44° to 64°) postoperatively and at follow-up was 36.9° (range, −36° to 58°).

Radiographic data for the patients included in the study can be found in Table 2.
An average of 4.6 (range, 3–7) chevron osteotomies and 6 (range, 5–8) concave rib osteotomies were performed during surgery. The average bleeding that occurred during surgery was 989 cc, whereas the average duration of surgery was 292 min, intraoperative transfusion was 2.3 units, and postoperative intensive care unit stay was overnight (Table 1). All patients were mobilized according to routine practice and received no dedicated physical therapy. The average duration of hospital stay was 6.7 days (range, 4–17 days).

No postoperative neurologic complications occurred in this patient group. Two alerts on transcranial electric motor evoked potential monitoring occurred during the surgeries (>65% drop in amplitude), on which surgery was paused, mean arterial pressure elevated, and correction released to the point at which the amplitude returned to normal. There was, however, one intraoperative pneumothorax, which was managed with a chest tube that was kept in for 3 days. One other patient had postoperative pneumonia that began with fever and productive cough on Postoperative day 2 but resolved without sequelae with appropriate intravenous antibiotics and chest therapy.

At the conclusion of at least 2 years of follow-up, none of the patients reported pain. No implant failures were observed, and no increase in residual deformity more than 10° occurred. For these reasons and according to the previous literature, it was concluded that none of the patients suffered from a failure of fusion or pseudoarthrosis [24]. Performed on the last follow-up, the average scores for the five domains of SRS-22 were 4.3, 4.4, 4.2, 4.1, and 4.8 for function, pain, self-image, mental health, satisfaction, and total, respectively.

### Discussion

The aim of any surgery on the deformed spine is to achieve a safe, well-corrected, balanced, cosmetically acceptable vertebral column that also remains that way for the rest of the patient’s life [1,8]. Congenital kyphoscoliosis is by its nature a rigid deformity that often requires spinal osteotomy to attain the necessary flexibility to restore the balance of the spinal column in modern times [2,8]. There have been reports about many types of spinal osteotomies and perhaps as many, if not more, reports on the modifications of these techniques in the treatment of congenital kyphoscoliosis [2,3,7,10–14,16,18,25]. Simultaneous or staged anterior-posterior approaches have been the gold standard in the treatment of rigid deformities of the spine in the past [3–5]. These techniques usually incorporate a release procedure performed through the anterior approach either open or endoscopic. The posterior approach is then used for instrumentation and further releases performed on the posterior elements. This can be performed simultaneously with the patient in the lateral decubitus position, either after the completion of the anterior procedure with repositioning of the patient or in a staged manner in which it is performed several days after the anterior procedure. As the combined surgical time increases and second incision is added to the procedure, intraoperative bleeding expectably also rises. Despite being a demanding method of treatment for the patient and surgeon, good results have been achieved with this technique in the past [3,4]. However, the anterior approach is associated with increased pulmonary complications, regardless of whether it is performed through an open or endoscopic way. Coe et al. [26] reported an overall complication rate of 10.2% for anterior-posterior fusion in their review of the Morbidity and Mortality database.

### Table 1

<table>
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<th>ID</th>
<th>Age (y)</th>
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<th>Associated disease</th>
<th>Prior surgery</th>
<th>Bleeding (mL)</th>
<th>Operating time (min)</th>
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<td>Yes—previous fusion</td>
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<td>255</td>
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<td>16</td>
<td>M</td>
<td>No</td>
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<td>M</td>
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<td>F</td>
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<td>270</td>
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<td>14</td>
<td>15</td>
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<td>M</td>
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<td>M</td>
<td>No</td>
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<td>F</td>
<td>Tethered cord</td>
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<td>1,100</td>
<td>240</td>
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<tr>
<td>18</td>
<td>12</td>
<td>M</td>
<td>No</td>
<td>750</td>
<td>240</td>
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ID, patient identification number; M, male; F, female.
of the Scoliosis Research Society, which corresponds to roughly twice that reported for either anterior or posterior procedures. Dobbs et al. compared patients with adolescent idiopathic scoliosis curves more than 90° that were divided into two groups: same-day or staged anterior and posterior fusion with hook and pedicle screw instrumentation versus posterior-only fusion and all-pedicle screw instrumentation. They found that patients undergoing posterior-only fusion had similar rates of correction compared with those in the anterior-posterior group and significantly less negative impact on the pulmonary system [27].

Other than these general problems, two-stage surgery has two other serious disadvantages that must be considered during surgery for congenital kyphosis: To expect increased flexibility from an anterior discectomy, there needs to be present a disc anteriorly, be it degenerated, narrow, contracted, or otherwise. In patients with congenital kyphosis, there is usually not even a remnant of a disc found anteriorly. Also, after the contracted structures anteriorly (anterior longitudinal ligament, disc, posterior longitudinal ligament) are released, a corrective maneuver performed from a posterior approach will cause the fulcrum of movement to shift posteriorly and the anterior and middle columns to lengthen relatively. This will pose a serious risk for the circulation of the spinal cord.

These difficulties with the combined approach have encouraged surgeons to find and refine posterior-only approaches for the treatment of rigid curves. With the arrival
of the pedicle screw instrumentation and the improved rates of correction with the segmental three-column fixation that it provides, a posterior-only surgery has become more popular for almost all deformities.

Instrumental to the success of posterior-only deformity correction are the posterior vertebral osteotomies. Posterior osteotomies serve to make the curve more flexible and prevent stretching of spinal cord by shortening the posterior column. First defined by Smith-Petersen in 1969 for the correction of rigid flexion deformity of the spine as encountered in rheumatoid arthritis, the lamina is resected (sometimes in a chevron shape) as necessary to have more room for the compression that follows [10]. The disc space is used as a fulcrum to effect anterior lengthening, and posterior shortening is carried out by compression of the created defect in the lamina [10,12,13]. The classic indication for a Smith-Petersen, or chevron, osteotomy would be a round gradual kyphosis like that encountered in Scheuermann disease. While allowing significant flexibility for the posterior elements, its applicability to short rigid kyphoses is limited as the disc space in these deformities is often nonexistent. Also, limited sagittal plane correction and a greater likelihood for coronal decompensation are among other reasons for concern.

Another posterior-only osteotomy, the pedicle-subtraction or eggshell osteotomy, achieves correction through all the three columns despite a posterior-only approach without anterior column lengthening that would cause stretching of the viscera and major vessels anterior to the spine [9,14,15,25]. When used for the correction of kyphosis, the degree of correction achieved at the osteotomy level has been reported to range from 26.1% to 40.1%.

![Preoperative and postoperative radiographs and 3-dimensional computed tomography image of a 14-year-old female patient treated with all-pedicle screw instrumentation, multiple chevron osteotomies, and concave rib osteotomies.](image)

**Table 2**

<table>
<thead>
<tr>
<th>ID</th>
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<th>Postoperative</th>
<th>Final follow-up</th>
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<tr>
<td></td>
<td>Scoliosis</td>
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<td>66</td>
</tr>
<tr>
<td>6</td>
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<td>T8–L3</td>
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*ID, patient identification number.*
with an average of 32%. However, a high rate of neurologic deficit has also been reported: 11.1% with 2.8% remaining permanently [9]. Because the correction is achieved only at the osteotomized level, pedicle-subtraction osteotomy is indicated for deformities in which there is sharp angulation at a single level, such as posttraumatic and degenerative flat back deformities. It is not recommended for congenital deformities in which more than one segment is involved in the deformity.

Posterior-only vertebral column resection, or PVCR, has recently been popularized by Suk et al. [6], first for fixed lumbar deformities and then for severe rigid scoliosis [7,28]. The procedure consists of the resection of all posterior elements, the facet joints above and below and the entire vertebral body and adjacent discs. Posterior vertebral column resection has been used in the surgical treatment of sharp angular kyphotic deformities in the thoracic and thoracolumbar spine. In their series of 38 adult patients with congenital kyphoscoliotic deformity, Suk et al. [6] reported correction rates of 67% in the coronal and 42% in the sagittal plane with a complication rate of 29%. Posterior vertebral column resection has recently also been applied to the pediatric age group. Lenke et al. [29] noted major curve improvements in their series of 35 children with curves of a congenital, idiopathic, or neuromuscular nature that were treated by PVCR (51% in scoliotic, 55% in globally kyphotic, 58% in angularly kyphotic, and 60% in congenitally scoliotic cases) but with a 40% overall and 11.4% neurologic-only complication rates. Although the most powerful method for the correction of deformity, PVCR carries with it the significant risk of complications and the shortening of a vertebral column already short from deformity.

The concept of concave rib osteotomy was introduced by Flinchum [18] in 1963. It should be considered as a release procedure in which the tether of the ribcage on the spine on the concave side is divided, and the flexibility of the scoliotic curve is thus increased. Concave ribs are longer than convex ribs in scoliotic deformities. Osteotomizing concave ribs allows the deformed spine to be translated to the midline. In an experimental study, Halsall et al. [19] have tested the flexibility of the spine in cadavers before and after sectioning of the ribs on the tension side and have found that deflection increases on an average of 53%. Clinical studies have supported these findings by showing the effectiveness of concave rib osteotomy in the treatment of rigid curves [20–22]. By combining concave rib osteotomies with chevron osteotomies, we have attempted to increase the flexibility of the congenital, multisegment involving rigid kyphoscoliotic curves of our patients. Also, concave rib osteotomies close to the apex allowed us to easily translate the spine to the midline during correction. We have found that scoliosis correction achieved by this method was 63%; sagittal balance was restored in all our patients, and all this was achieved with average operating times and average intraoperative bleeding well below those previously reported for combined anterior-posterior and posterior-only vertebral resection. Perhaps most important of all, we encountered no neurologic deficit of any kind.

The patients’ functional and cosmetic outcomes were also highly improved at 2-year follow-up. It was impossible to obtain preoperative SRS-22 results for this group of patients as the majority of them were operated on before the Turkish version of the SRS-22 questionnaire was validated. The lack of preoperative data makes it impossible to determine how much benefit the patients derived from their operations in this regard. However, our final follow-up data show that although these patients have a complex deformity and underwent a complex surgery, they are at a similar level with patients who have undergone simpler spine surgery.

One such study published in 2011 reported an average SRS-22 score of 3.8 for the instrumented group versus 4.1 for the uninstrumented group with no difference in domains between the groups [30]. In a different study on adolescent idiopathic scoliosis patients, the postoperative total SRS-22 score was found to be 4.27 [31]. In a 2010 study on patients undergoing anterior fusion, the average postoperative total SRS-22 score was observed to be 4.4 [32]. These studies were performed on patients with deformities that could be considered less severe than the patients in our series. The final total SRS-22 scores are comparable with those obtained at follow-up in our study. We suggest that the reader interprets our data in light of these previous studies.

With this retrospective case series, we have attempted to show that the combination of multiple chevron and concave rib osteotomies, previously shown to be effective for rigid and neglected idiopathic deformities, with the additional correction potential and stability provided by an all-pedicle screw instrumentation, can be effectively used as an alternative in the treatment of rigid congenital curves involving more than three levels or multiple curves separated by at least two segments that would otherwise require multiple vertebral resections. This technique appears to be a safe and effective method. However, for sharp, angulated short-segment deformities that already have neurologic symptoms, PVCR should be preferred in experienced hands and advanced centers despite all its risks.

References


[7] Suk SI, Kim JH, Kim WJ, et al. Posterior vertebral column resection, or PVCR, has recently been popularized by Suk et al. [6], first for fixed lumbar deformities and then for severe rigid scoliosis [7,28]. The procedure consists of the resection of all posterior elements, the facet joints above and below and the entire vertebral body and adjacent discs. Posterior vertebral column resection has been used in the surgical treatment of sharp angular kyphotic deformities in the thoracic and thoracolumbar spine. In their series of 38 adult patients with congenital kyphoscoliotic deformity, Suk et al. [6] reported correction rates of 67% in the coronal and 42% in the sagittal plane with a complication rate of 29%. Posterior vertebral column resection has recently also been applied to the pediatric age group. Lenke et al. [29] noted major curve improvements in their series of 35 children with curves of a congenital, idiopathic, or neuromuscular nature that were treated by PVCR (51% in scoliotic, 55% in globally kyphotic, 58% in angularly kyphotic, and 60% in congenitally scoliotic cases) but with a 40% overall and 11.4% neurologic-only complication rates. Although the most powerful method for the correction of deformity, PVCR carries with it the significant risk of complications and the shortening of a vertebral column already short from deformity.

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