Assessment of Rib Hump Deformity Correction in Adolescent Idiopathic Scoliosis With or Without Costoplasty Using the Double Rib Contour Sign

Marios G. Lykissas, MD, PhD, Vivek Sharma, MD, and Alvin H. Crawford, MD, FACS

Division of Orthopaedic Surgery, Cincinnati Children’s Hospital Medical Center, University of Cincinnati, Cincinnati, OH 45229

Conflict of interest: There are no conflict of interest

Corresponding author
Alvin H. Crawford, MD, FACS
Cincinnati Children’s Hospital Medical Center
Division of Orthopaedic Surgery
3333 Burnet Avenue, MLC 2017
Cincinnati, OH 45229
Phone: (513) 636-1383, Fax: (513) 636-3928
Email: Alvin.Crawford@cchmc.org
Study Design: Level III; Therapeutic study

Objective: The purpose of this study was to determine whether the addition of costoplasty in AIS surgery improved correction of the rib hump deformity.

Background: Trunk deformity is comprised of vertebral rotation, posterior vertebral element, and rib deformities. Surgical correction of the rotational deformity has been performed by segmental spinal instrumentation with vertebral derotation, but complete correction of the rib hump by derotation is rarely achieved.

Methods: A multi-center registry database for AIS was reviewed with the inclusion criteria of Lenke type I curves treated with posterior spinal fusion with or without costoplasty, instrumented with pedicle screws or hybrid constructs, with a minimum follow-up of 2 years. The first group (Group I) was treated with pedicle screws, direct vertebral rotation and no costoplasty while the second group (Group II) was treated with pedicle screws, vertebral rotation and costoplasty. The rib index (RI), calculated from the double rib contour sign (DRCS), and Cobb angle were measured radiographically and compared between groups.

Results: The groups were comprised 36 subjects in Group I and 40 subjects in Group II. The mean preoperative Cobb angles for groups I and II were 49.7º and 49.8º, respectively, while the mean postoperative Cobb angles were 10.2º and 10.9º, respectively. There was no difference in preoperative as well as postoperative values when comparing both groups (p=0.48 and p=0.96, respectively). Before spine surgery, RI for groups I and II was 1.61, and 1.80, respectively. Postoperatively, the rib indices were 1.39 for Group I and 1.29 for Group II. These differences were found to be statistically significant (p=0.002 and p=0.006, respectively). The amounts of correction of RI were 0.23 and 0.51 for groups I and II, respectively. This difference was found to be statistically significant (p<0.0001). The correction percentages were 13.7% and 28.3%, respectively. This difference was also found to be statistically significant (p<0.0001).
Conclusions: Costoplasty combined with pedicle screws and vertebral derotation, may significantly improve rib hump deformity as opposed to pedicle screws and vertebral derotation alone.

Key Words: rib index, costoplasty, rib hump, adolescent idiopathic scoliosis, double rib contour sign
INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a three dimensional deformity involving both the spine and the thoracic cage. Although the orthopedic surgeon is primarily concerned with the magnitude of the curvature, its propensity for progression and possible deleterious effects to the cardiopulmonary system, often it is the cosmetic component of the deformity that concerns most parents and patients who present to the clinic. The patients’ initial presenting complaint maybe due to the external manifestations of the condition which include rib hump, asymmetry of shoulder level, prominent scapula, breast and pelvic asymmetry or back discomfort. Cosmesis is perceived by the child to be an important component of the deformity and relates to the family’s (parent and patient) perception of successful treatment.1,2

Treatment should be able to address all the facets of the deformity. Treatment methods have all been designed to address the spinal deformity. The introduction of Harrington rod instrumentation revolutionized the treatment of scoliosis affording correction through distraction forces. For a time, Harrington rod instrumentation was the standard treatment of scoliosis, but derotation of the apical vertebra was minimal,3-5 as well as correction of the rib hump deformity.6 In order to address the rib deformity, a resection of the ribs had to be performed in most cases.

Since Volkmann7 in 1889 performed the first rib resection for scoliosis, costoplasty has been used to improve the rib hump deformity in conjunction with spine fusion surgery for cosmetic reasons. Studies have shown a 71% reduction in rib prominence with the use of costoplasty.8 In addition, this procedure provides a reasonable amount of bone graft.7,9 The theoretical disadvantage of performing a costoplasty was its effect on pulmonary function and the added morbidity from the procedure. However, more recent studies showed no significant pulmonary compromise at a minimum follow-up of 2 years after costoplasty.10 The advent of pedicle screw instrumentation along with direct vertebral derotation (DVR) techniques, and the application of single rod derotation (SRR), correction of the three dimensional deformity of the spine was achieved more efficiently than with conventional non-segmental fixations.11
These techniques were able to reduce the rib hump, but not to the degree that satisfied all patients’ and surgeons’ concerns in this regard.10

Assessment of the deformity in the coronal and sagittal plane are dependent on straightforward radiographic measurements of the Cobb angles. Assessment of the rotational deformity is far less clear. Cobb12 used a spinous process position to assess vertebral rotation, while Nash and Moe13 used the pedicle shadow to assess the vertebral rotation. Bunnell14 used a scoliometer to measure trunk deformity, assuming it is dependent on the surface deformity to assess the spinal deformity. Likewise, Perdriolle15,16 used the pedicle shadow and measured the rotation angle through a line drawn through the convex pedicle. No such methods had been previously purposed to assess rib prominence by radiographic methods. Grivas et al.17 introduced the rib index (RI) method extracted from the double rib contour sign (DRCS) to evaluate rib hump deformity in idiopathic scoliosis patients, attempting to create a safe reproducible way to assess the rib hump deformity based on lateral radiographs.

The goal of the present study is to validate the role of costoplasty in the treatment of AIS patients using the DRCS and RI and to evaluate whether the addition of costoplasty to the fusion procedure aids in better correction of the rib hump deformity.

METHODS

After institutional review board (IRB) permission was obtained, a multi-center registry database for AIS was reviewed for cases diagnosed with Lenke type 1 curve patterns treated with a posterior instrumented spinal fusion. Only those cases treated with all pedicle screw constructs with or without costoplasty were included in the study. Patients had to have had at least 2 years follow-up to be included in the study.
Patients were then classified into 2 groups based on their instrumentation; patients instrumented with all pedicle screw constructs and no costoplasty were placed in Group I, and patients who were instrumented with all pedicle screw constructs and costoplasty in Group II. All pedicle screw constructs were defined as those where pedicle screws comprised a minimum of 80 percent of the construct. These were segmental screws constructs with bilateral screws at the apex of the deformity.

Direct vertebral derotation technique was utilized in all patients in order to derotate several vertebrae as a unit. In order to achieve sagittal alignment and aid in axial derotation differential rod contouring was also performed. After bending the rod into the planned sagittal alignment, the concave rod was inserted first, except in cases of hyperkyphosis where the convex rod was placed first to allow for lordosing during correction. The rod was then gradually translated while capturing each set screw from proximal and distal toward the apex. After placement of the rods with the set screws remaining loose the DVR maneuver was performed. The DVR technique included attachment of the correction posts over screws located at the curve apex and application of gentle constant force to the apical segments while manual pressure was applied on the rib prominence. The screw-bone interface was carefully monitored while the derotation was performed to early detect and prevent screw fixation failure. After achieving the desired derotation, the set screws were tightened at each level.

Costoplasty was carried out on the convex side of the scoliotic curve when residual rib hump deformity was clinically noted following derotation maneuvers. Adequate pulmonary function was an absolute prerequisite for costoplasty. After the spinal deformity had been instrumented the transverse process was removed with a rongeur through a paramedian approach. A 2-cm segment of the posterior rib centered on the costotransverse articulation was then resected after meticulous elevation of the pleura and neurovascular bundle. Care was taken so that the resected portion of the rib was longest at the apex. Three to 5 ribs on the convex side of the curve were resected with the 10th rib being the lowest rib resected. A chest tube was placed in all cases.
Data points collected include demographic data, type of construct, implants used, and use of costoplasty. Pre- and postoperative radiographs were analyzed using e-Film 1.81 version, 1998-2002, e-Film Medical Inc. We measured scoliosis by the Cobb angle, and the rib hump deformity by DRCS and RI, as described by Grivas et al. The RI was calculated by the ratio of spine distances d1/d2 (Fig. 1), where d1 is the distance between the most extended point of the most extending rib contour and the posterior margin of the corresponding vertebra on the lateral scoliosis films, while d2 is the distance from the least projection rib contour and the posterior margin of the same vertebra. The amount of RI correction was calculated by subtracting the postoperative RI from the preoperative RI. The correction percentage was calculated using the following equation:

\[
\text{RI Correction (\%)} = \frac{\text{Preoperative RI} - \text{Postoperative RI}}{\text{Preoperative RI}} \times 100
\]

All measurements were performed by one of the authors.

Student \( t \)-test analysis was used to compare the different groups. All tests were calculated with use of the SPSS, version 16.0 (SPSS Inc., Chicago, IL) statistic package for personal computers. In all instances, \( p < 0.05 \) was regarded as statistically significant.

**RESULTS**

A total of 76 patients were included in the study. The mean follow-up was 44 months (range; 27 to 68 months). All surgeries were performed between 2002 and 2006. There were 36 patients in Group I, and 40 in Group II. The mean ages for Group I and Group II were 14.6 years (range; 10 to 19 years) and 15 years (range; 10 to 19 years), respectively. There was no statistical significance found between the ages in the 2 groups (\( p=0.48 \)).
For Group I, the mean preoperative Cobb angle was 49.7º +/- 9.2º and the mean postoperative Cobb angle was 10.2º +/- 3º (Table 1). For Group II, the mean preoperative Cobb angle was 49.8º +/- 9.4º and the mean postoperative Cobb angle was 10.9º +/- 3.5º. There was no difference in preoperative as well as postoperative values when comparing the 2 groups (p= 0.48 and p=0.96, respectively).

The mean preoperative RI for Group I was 1.61 +/- 0.19 and the mean postoperative RI was 1.39 +/- 0.13 (Table 1). For Group II, the mean preoperative RI was 1.80 +/- 0.3 while the mean postoperative RI was 1.29 +/- 0.11. There was statically significant difference in the RI between groups both preoperatively and postoperatively (p=0.002 and p=0.0006, respectively). The amounts of correction of RI were 0.23 and 0.51 for groups I and II, respectively (Table 2). This difference was found to be statistically significant (p<0.0001). The correction percentages were 13.7% and 28.3%, respectively. This difference was also found to be statistically significant (p<0.0001).

Postoperative complications included mild pleural effusion in 4 patients in Group II which was completely resolved during the first postoperative radiographic follow-up at 6 weeks after surgery. At the last follow-up, there was no numbness or hyperesthesia of the skin overlying the costoplasties. All patients tolerated the chest tube well. No complications were recorded in Group I.

**DISCUSSION**

Scoliosis is a three dimensional deformity which occurs in three planes, the coronal, the sagittal, and axial planes. It has an incidence of 5% with a female to male ratio of 1.25:1, but varies with the magnitude of the curve. Scoliosis often results in a deformity of the thoracic cage which is a primary concern for the family and the patient as it causes a significant cosmetic problem. This often has a negative effect on the patients self image as well as self esteem.
The rib hump deformity is a consistent concern for both the patients’ family and the orthopaedic surgeon and a major cause of spinal revision surgery in adolescent idiopathic scoliosis patients. Studies have shown that the development of the rib hump may precede the development of spine deformity. In an animal study, Agadir et al. demonstrated that scoliosis may be induced by rib stimulation in rabbits. In fact, thoracic cage asymmetry may be present even in those cases with minimal or without spinal curvatures. In his review of 133 cases, Grivas et al. using DRCS found that a rib hump was present even without spinal deformity in 30% of the cases.

Assessment of the severity of the deformity of the thoracic cage is based on both clinical and radiographic measures. This should be reproducible and easy to apply. Multiple methods have been proposed to radiographically assess the rotational deformity of the ribs with the Nash, Moe and Pedriolle methods remaining the most commonly used. However, these methods do not assess the degree of rib deformity affecting the thoracic cage. The DRCS is considered an excellent method of assessing rib hump deformity due to its simplicity and the ability to be calculated on the lateral scoliosis film with no need for special imaging or additional exposure to radiation.

Management of spinal deformity should ideally address all three planes of the deformity. However, it is the external effect of treatment that is of the utmost concern to the patient and the patients’ family. Prior to pedicle screw instrumentation, the rib hump had to be addressed directly by performing costoplasties. Costoplasty while adding time to the length of the procedure, has the advantage of providing bone graft for use in the fusion and significant improvement to rib hump appearance (Fig. 2). It also carries the disadvantage of added morbidity and possible detrimental effect in the postoperative pulmonary function. The development of pedicle screw instrumentation and spinal derotation techniques has given surgeons the power to address the deformity in all three planes which include in part an ability to address the rib hump deformity. Some authors feel that posterior pedicle screw instrumentation alone with derotation techniques is adequate in addressing the rib deformity. These factors have greatly decreased the popularity of costoplasties in its use to address the rib hump deformity. Other authors feel...
that the correction maybe inadequate and costoplasties are necessary to achieve full correction of the rib hump.\textsuperscript{26,27} Costoplasty is not without complications. Among those reported are pleural tear, pleural effusion, rib concavity, and residual deformity. Four of our patients developed mild pleural effusion which was completely resolved the first weeks after surgery. The detailed procedure is beyond the scope of the current study.

To address this query, Suk et al.\textsuperscript{10} retrospectively reviewed 87 patents with AIS treated with pedicle screw fixation. The patients were divided into 3 groups, i.e., patients with no costoplasty, costoplasty with DVR, and costoplasty with DVR. There were no difference in the spinal balance and pulmonary function among the 3 groups, while costoplasty with DVR had the highest correction rate of the rib hump with respect to the other 2 groups. The authors concluded that costoplasty allowed better rib hump correction and satisfactory clinical outcome without pulmonary function compromise.\textsuperscript{11} Our series showed significant differences in the rib hump deformity pre- and postoperatively between both groups. It should be noted that although Group II had higher RI value preoperatively, indicating a more severe rib hump deformity, the postoperative RI showed an overall better correction with DVR and costoplasties versus DVR alone. This clearly shows that costoplasties combined with a posterior spinal fusion provide excellent correction of the thoracic cage deformity.

However, the question still arises as to the effect of costoplasties on pulmonary function. Though, this issue was out of the scope of our current study, Suk et al.\textsuperscript{10} showed no statistical difference in postoperative pulmonary function at final follow-up between all their 3 groups as compared to preoperative values, even if the postoperative values were slightly decreased. Steel et al.\textsuperscript{7} reviewed 370 scoliotic patients treated by posterior spinal fusion instrumentation and costoplasty. Their results showed that although pulmonary function decline for the first 2 postoperative weeks, pulmonary function values improved gradually, and after 3 years of follow-up all patients had equal or improved pulmonary function. Min et al.\textsuperscript{27} performed a retrospective review of 21 patients with AIS treated with posterior
spinal fusion with pedicle screw instrumentation and costoplasty followed for an average of 24 months. They found no change in pulmonary function at final follow-up.

Limitations of our study include its retrospective design, the variable quality of scoliosis films, and its, multi-center nature with potentially different clinical criteria for costoplasty.

CONCLUSIONS

A major concern to AIS patients and spine surgeons is rib hump deformity as a part of scoliosis deformity. The RI is a useful tool to measure the rib hump deformity. Our study strongly infers that costoplasty combined with pedicle screws and vertebral derotation, may significantly improve rib hump deformity as opposed to pedicle screws and vertebral derotation alone. We strongly advise making families aware of the potential transient decrease in pulmonary function testing with the caveat that no series has reported clinical deficiencies.
REFERENCES


Figure Legends

Fig. 1. A. Line diagram demonstrating the RI using the double rib contour sign (DRCS). d1 is the distance between the most extended point of the most extended rib contour and the posterior margin of the corresponding vertebra on the lateral scoliosis film. d2 is the distance from the least projection rib contour and the posterior margin of the same vertebra. RI equals d1/d2. B. Preoperative RI in patient A in Group I. C. Postoperative RI in patient A in Group I. D. Preoperative RI in patient B in Group II. E. Postoperative RI in patient B in Group II.

Fig. 2. Posteroanterior and lateral film of a 12 year-old female Lenke type 1B adolescent idiopathic scoliosis and severe rib hump deformity as noted on the lateral films (A, B). The patient subsequently underwent a selective thoracic fusion from T3 to L1 followed by costoplasty which afforded adequate correction of the rib hump deformity as seen on the postoperative lateral films (C, D).
Table 1. Summary of results for groups I and II.

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<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Mean age (years)</td>
<td>14.6</td>
<td>15.0</td>
<td>0.484</td>
</tr>
<tr>
<td>Pre-op Cobb angle</td>
<td>49.7°±9.2°</td>
<td>49.8°±3°</td>
<td>0.960</td>
</tr>
<tr>
<td>Post-op Cobb angle</td>
<td>10.2°±9.4°</td>
<td>10.9°±3.5°</td>
<td>0.490</td>
</tr>
<tr>
<td>Pre-op RI</td>
<td>1.61±0.19</td>
<td>1.80±0.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Post-op RI</td>
<td>1.39±0.13</td>
<td>1.29±0.11</td>
<td>0.0006</td>
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A p-value < 0.05 was considered to be significant

Table 2. Amount of RI correction and percentage of correction

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<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Amount of correction</td>
<td>0.23</td>
<td>0.51</td>
<td>0.0001</td>
</tr>
<tr>
<td>Percentage of correction</td>
<td>13.7%</td>
<td>28.3%</td>
<td>0.0001</td>
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A p-value < 0.05 was considered to be significant