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Effectiveness and safety of a modified (rib ends fixed under transverse process) thoracoplasty for rib hump deformity in adults with severe thoracic scoliosis

A retrospective study

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Abstract

Razor back deformity is one of the most noticeable problems of severe scoliosis. Thoracoplasty has been reported to be a useful approach to correct the rib hump deformity. However, the outcomes of thoracoplasty in patients with severe, rigid, thoracic scoliosis have not yet been evaluated.

To evaluate the effectiveness and safety of a modified technique of thoracoplasty (rib ends fixed under transverse process) for rib hump deformity in adults with severe thoracic scoliosis and severe pulmonary dysfunction.

Patients with severe thoracic scoliosis and severe pulmonary dysfunction who underwent staged surgical strategy including halo-pelvic traction, spinal osteotomy combined with the modified thoracoplasty were included. To avoid paradoxical breathing result from multiple rib resections and enlarge the capacity of thoracis, the ends after rib resection were fixed under transverse process compared with conventional thoracoplasty. Patients were excluded on the basis of pulmonary diseases and inadequate follow-up. Data on deformity correction and pulmonary complications were reviewed. A *t* test was performed on the pre- and postoperative data of pulmonary function, height of the rib hump deformity, and total lung area.

Eighteen patients (5 men and 13 women) with a major thoracic curve of >130° were included. The mean age of patients was 25.3 ± 3.6 years (range, 19–32 years), with an average length of follow-up of 30.2 months. After application of halo-pelvic traction, the mean major thoracic curve decreased from 168.2° ± 14.28° to 97.3° ± 10.75° and the thoracic kyphosis decreased from 159.4° ± 20.60° to 94.8° ± 9.58°. On average, 6.3 (range, 4–8) ribs were resected. The height of the rib hump decreased from 84.6 ± 13.3 to 15.3 ± 3.4 mm. The average predicted forced vital capacity (FVC%) before surgery was 37.2 ± 13.30%, indicative of severe pulmonary impairment, with a small but non-significant improvement in the FVC% at the final follow-up. The mean total lung area increased from 2583.2 ± 501.36 to 2890.1 ± 537.30 mL at the last follow-up. No severe pulmonary complications occurred.

Our modified approach to thoracoplasty procedure is effective and safe in correcting a razor back deformity in patients with severe, rigid, scoliosis, and severe pulmonary dysfunction, without causing any significant change in long-term pulmonary function.

Abbreviations: AIS = adolescent idiopathic scoliosis, CT = computed tomography, DVBD = direct vertebral body derotation, FVC = forced vital capacity, FVC% = predicted forced vital capacity, HFT = halo-femoral traction, HGT = halo-gravity traction, HPT = halo-pelvic traction, PFT = pulmonary function test.

Keywords: halo-pelvic traction, pulmonary function test, rib hump deformity, severe and rigid, severe pulmonary dysfunction, thoracic scoliosis, thoracoplasty, total lung area

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BY and DZ have contributed equally to this work and should be considered as co-first authors.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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1. Introduction

A razor back deformity is one of the most important complications among patients with severe scoliosis, with possible negative impacts on cosmesis, pulmonary function, pain, and self-esteem.[1] Therefore, the presence or absence of a razor back deformity can significantly influence clinical outcomes of the surgical correction of severe scoliosis.[2,3] Concomitant thoracoplasty with corrective spinal surgery is useful, in this regard, to maximally reduce the rib hump deformity.[2,4,5]

Although different approaches to thoracoplasty have been developed, the traditional approach to correct a rib hump deformity consists of resection of selected ribs, extending from the costovertebral junction (medially) to the posterior axillary line (laterally).[6] Early research reported satisfactory clinical outcomes for rib hump correction via thoracoplasty in adolescents with idiopathic scoliosis, without significant impairment in pulmonary function impairment.[2,4,7] More recent reports, however, have pointed out that thoracoplasty may impair pulmonary function during the preoperative period.[8–10] Despite this evidence, thoracoplasty is still indicated for patients with severe thoracic curves who are expected to have a low response to spinal correction for rib hump reduction.[10]

To our knowledge, no prior study has reported on the outcomes of thoracoplasty performed in extreme cases of scoliosis severity (Cobb angle $>130°$) combined with severe pulmonary dysfunction. In this study, we describe our modified thoracoplasty method for correction of a rib hump deformity, which was designed to improve the thoracic mobility in patients with severe, rigid, thoracic scoliosis. To evaluate the effectiveness and safety of our modified thoracoplasty approach, we retrospectively reviewed the change in radiological and functional data of patients underwent the modified thoracoplasty approach, from baseline (before surgery) to the final postoperative follow-up.

2. Materials and methods

Institutional Review Board approval was obtained from the local ethics committee of Chengdu Third People's Hospital on October 11, 2019 for this study and the IRB reference number was [2019]-S-103. As a retrospectively study, the hospital records of patients who underwent surgical spinal deformity correction for a severe, rigid, thoracic scoliosis at our institution, between February 2014 and February 2015, were reviewed. An approved consent form was signed by each patient before any operate was performed. Staged surgical strategy including halo-pelvic traction, spinal osteotomy combined with the modified thoracoplasty was made for these severe thoracic scoliosis patients. Patients were excluded on the basis of incomplete clinical data, pulmonary diseases, and follow-up <24 months.

Clinical variables obtained included pre- and postoperative Cobb's angle, angel of kyphosis, total lung area, rib hump, and outcome of pulmonary function test. Pre- and postoperative anterior–posterior and lateral x-ray films of standing whole spine were taken. Cobb angle of main thoracic curve and thoracic kyphosis were measured to evaluate outcomes. Total lung area measured by pre and postoperative computed tomography scans was defined as the volume of effective lung tissue and used as a proxy measure of thoracic volume. The rib hump height defined as the distance from the apex of the rib hump on the convex side to the apex of the concave rib at the same level was measured radiographically, using the technique described by Geissele et al.[1] Significant rib deformity was defined as a hump height of >3 cm. The severity of pulmonary impairments was classified according to the American Thoracic Society's guidelines, based on the forced vital capacity (FVC),[11] as follows: FVC% $>80\%$, no impairment; FVC% between 65% and 80%, mild impairments; FVC% between 50% and 65%, moderate impairments; and FVC% $\leq 50\%$, severe impairment. The FVC and the percentage of the predicted value (FVC%) measured on pulmonary function tests were used to evaluate the safety of our modified thoracoplasty approach on pulmonary function. Three spinal surgeons being blinded to each other completed radiological measurements to avoid bias of outcomes.

2.1. Surgical procedures

All surgeries were performed by the senior author, using a pedicle screw internal fixation system. The modified thoracoplasty is illustrated in Fig. 1. Patients were positioned in a prone position on the surgical table, with a posterior midline approach used, along the spinous process. The ribs around the apical vertebra on the convex side were exposed via lateral retraction through the same posterior incision. Ribs were resected from the costotransverse junction (medially), after meticulous sub-periosteal dissection, over a length of 2 to 4 cm. The number of ribs resected was based on the magnitude of rib hump, evaluated both before surgery and intraoperatively. The ends of the ribs were resected to an acceptable length, using a bone rongeur, with the ends placed into the groove under the transverse process to avoid paradoxical breathing result from multiple rib resections and enlarge the capacity of thoracis. A forceful suture was used to fix the end of each resected rib to the pedicle screw of the internal fixation

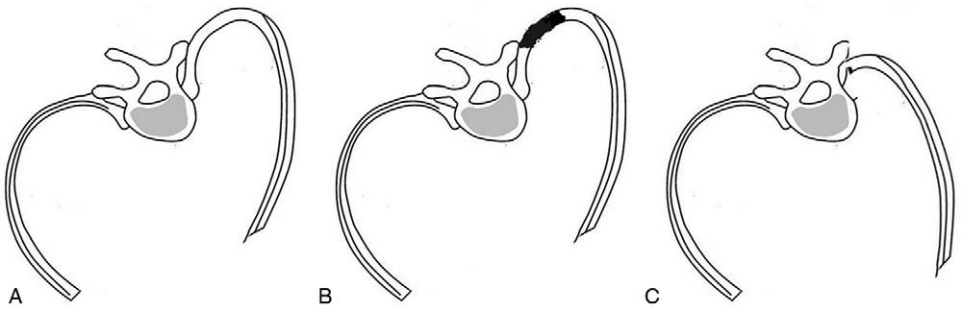

Figure 1. Illustration depicting the modified thoracoplasty procedure for residual rib hump. The images show an axial view of the rib cage at the thoracis level preoperatively (A) and intraoperatively (B, C).

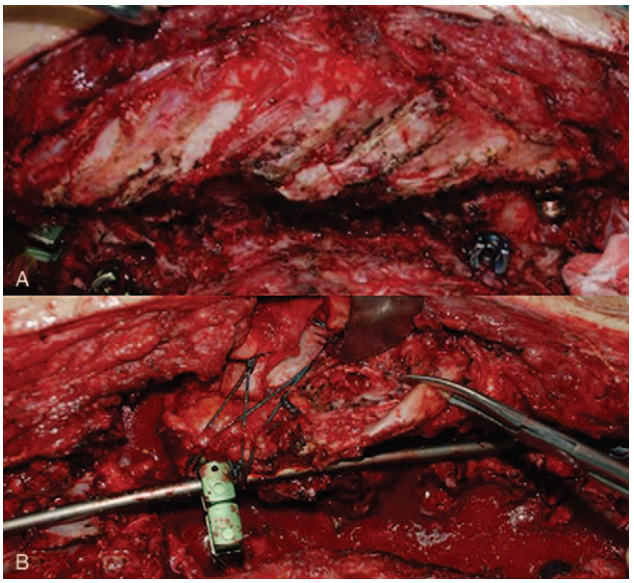

Figure 2. A. The lateral retraction of muscles for exposure of the convex ribs during scoliosis correction surgery. The vertebral body was near 90° rotation. B. The fixation of rib ends on pedicle screw internal fixation system.

system used to avoid olisthesis (Fig. 2). The number of ribs to be resected was determined by intraoperative comparison of the hump height between the convex and concave side. Subperiosteal dissection of the rib was meticulously performed to avoid pleural injury. Whether using pleural repair or a chest tube inserted into the pleural cavity depends on the size of pleural injury during the surgery.

2.2. Statistical methods

Statistical analyses were performed by the lead author. The statistical analysis was performed using the Statistical Product and Service Solutions software (version, 20.0). The quantitative variables were compared using a 2-sample *t* test after confirming that the values of the 2 groups were approximately normally distributed and the variances were approximately equal. The other quantitative variables had a skewed distribution and were therefore compared using a (non-parametric) Mann–Whitney *U* test. A *P*-value <.05 was considered significant.

3. Results

Eighteen patients (5 men and 13 women) presented with a minimum thoracic curve or kyphosis of >130° and underwent spinal deformity correction, with concomitant new thoracoplasty, were included. The mean age of the 18 patients was 25.3 ± 3.6 years (19–32 years). On admission, the mean major thoracic curve and kyphosis were, respectively, 168.2° ± 14.28° (range, 152–180°) and 159.4° ± 20.60° (range, 142–180°). All were assessed to have severe pulmonary dysfunction. Halo-pelvic traction was used to reduce the curve and to improve pulmonary dysfunction. After halo-pelvic traction, the mean major thoracic curve decreased to 97.3° ± 10.75° (range, 76–104°) and the thoracic kyphosis to 94.8° ± 9.58° (range, 75–100°). Spinal osteotomy and the modified thoracoplasty were performed at a suitable time. On average, 6.3 ribs were resected (range, 4–8 ribs) during the new thoracoplasty. The height of the rib hump decreased from 84.6 ± 13.3 to 15.3 ± 3.4 mm. The complications directly related to the modified thoracoplasty included pleural injury in 6 patients, 2 of whom required chest tube placement due to a large size pleural injury.

Table 1

Characteristics at preoperation of spinal deformity correction concomitant thoracoplasty and last follow-up.

Parameter	Pre-op	Final follow-up	*P* value
Thoracic curve cobb	97.3° ± 10.75°	48.25° ± 8.29°	<.05
Thoracic kyphosis	94.8° ± 9.58°	30.75° ± 13.80°	<.05
Rib hump, mm	84.6 ± 13.3	15.3 ± 3.4	<.05
FVC, L	1.24 ± 0.491	1.26 ± 0.470	>.05
FVC%	37.2 ± 13.30%	38.2 ± 13.25%	>.05
Total lung area, mL	2583.2 ± 501.36	2890.1 ± 537.30	>.05

FVC = forced vital capacity, FVC% = percent predicted forced vital capacity. *P* > .05 indicates non-significant difference. *P* < .05 indicates significant difference.

The average length of follow-up was 30.2 months (ranged, 24–36 months). The total lung area, FVC, and FVC% were not statistically different at the last follow-up than at baseline (before surgery) and were a little improved on average at the last follow-up visit. Radiological parameters and the pulmonary function test (PFT) results before surgery and at the last follow-up are reported in Table 1. Of note, there was no evidence of lung tissue involved in the rib hump tissue on preoperative CT images. The total lung area increased from a baseline of 2583.2 to 2890.1 mL after the combined scoliosis correction and new thoracoplasty, although this change was not significant.

All patients subjectively rated their outcome as excellent. Photographs of clinical appearance, obtained before and after management, are shown in Fig. 3, with pre- and post-treatment radiographs presented in Fig. 4.

4. Discussion

We demonstrate that our modified thoracoplasty was successful in achieving a satisfactory correction of the rib hump, with a correction rate of 81.9%, and an increase in the total lung area, and safety for pulmonary function. The modified thoracoplasty eliminated the dead space of the lungs without reducing the volume of thoracic cage (Fig. 5). Considering that there was no change in the volume of the thoracic cage, improvement in breathing movement of the thoracic cage after surgery may have contributed to the observed improvement in FVC and FVC%.

Rib hump deformity is one of the most prominent factors influencing the cosmetic appearance of patients with severe thoracic scoliosis.[12] As such, the outcome of the rib hump deformity correction is an important factor for patient's satisfaction following spinal correction of scoliosis.[7] Since first introduced by Steel in 1983,[6] thoracoplasty has become a mainstay component of the surgical correction of a rib hump deformity for patients with adolescent idiopathic scoliosis (AIS), with the associated benefit of improved flexibility of the curves.[13] The vertebral rotation causes a posterior rotation of the associated ribs on the convex side of the curve, resulting in a sharp angulation of the rib angle. Pedicle screw instrumentation provides rigid 3-dimensional correction for scoliosis, allowing a direct vertebral body derotation (DVBD) that may reduce the rib deformity without thoracoplasty.[3,14] However, for a prominent

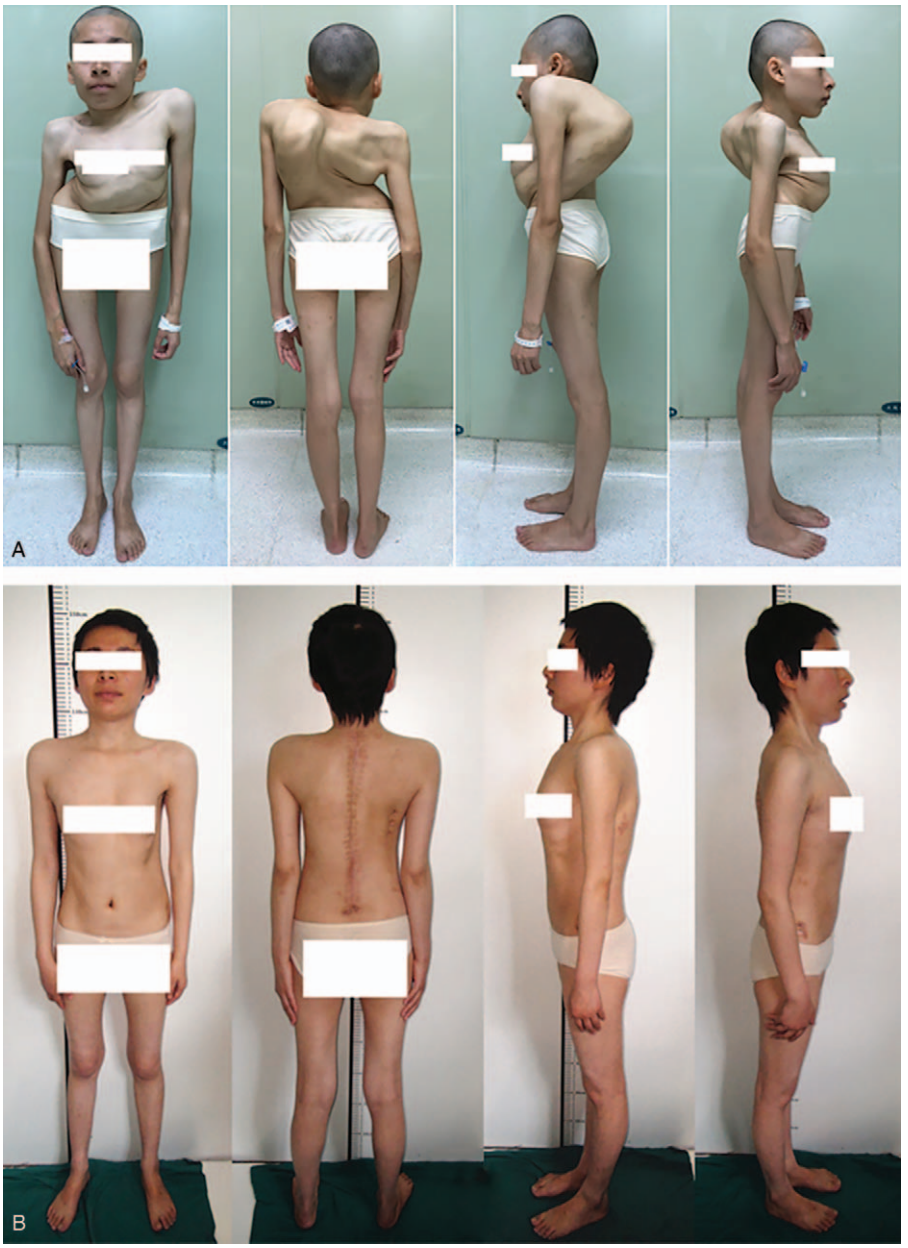

Figure 3. Photos of patient preoperatively (A) and postoperatively (B).

rib hump, thoracoplasty provides a better correction than DVBD alone.[3,15] As such, although thoracoplasty may impair pulmonary function, it is indicated for correction of a severe rib hump deformity.[10] We do note, however, that the usefulness of thoracoplasty for the correction of a rib hump deformity has largely been reported for cases of idiopathic scoliosis, without adequate examination of its usefulness in patients presenting with rigid thoracic scoliosis of extreme severity. In our study, we report the outcomes for a series of patients presenting with a minimum thoracic curve or kyphosis of >130°. The correction of severe and rigid scoliosis remains a surgical challenge in these cases, especially for patients with concomitant severe pulmonary impairment.[16,17] The high morbidity rate of perioperative respiratory complications makes it unfeasible to perform an effective correction.[18] Weinstein et al[19] reported a clinically relevant pulmonary impairment with progression of curves beyond 100°, with a strong correlation between curve severity and PFT results. Several method for gradual correction of the curve in patients with severe and rigid scoliosis have been developed, including halo-pelvic traction (HPT), halo-gravity traction (HGT), and halo-femoral traction (HFT).[20–22] Effective clinical outcomes have been reported for HGT,[23] while HPT, which has been addressed in a few reports, is not popular owing to its shortcomings.[24,25]

The main goal of the preoperative traction is to improve pulmonary function, avoid major neurological risk and to obtain gradual correction of severe and rigid scoliosis. In the surgical approach, HPT was used to reduce the lateral curvature and kyphosis. Our decision is based on a previous study that reported HPT to be effective for patients with severe and rigid scoliosis and

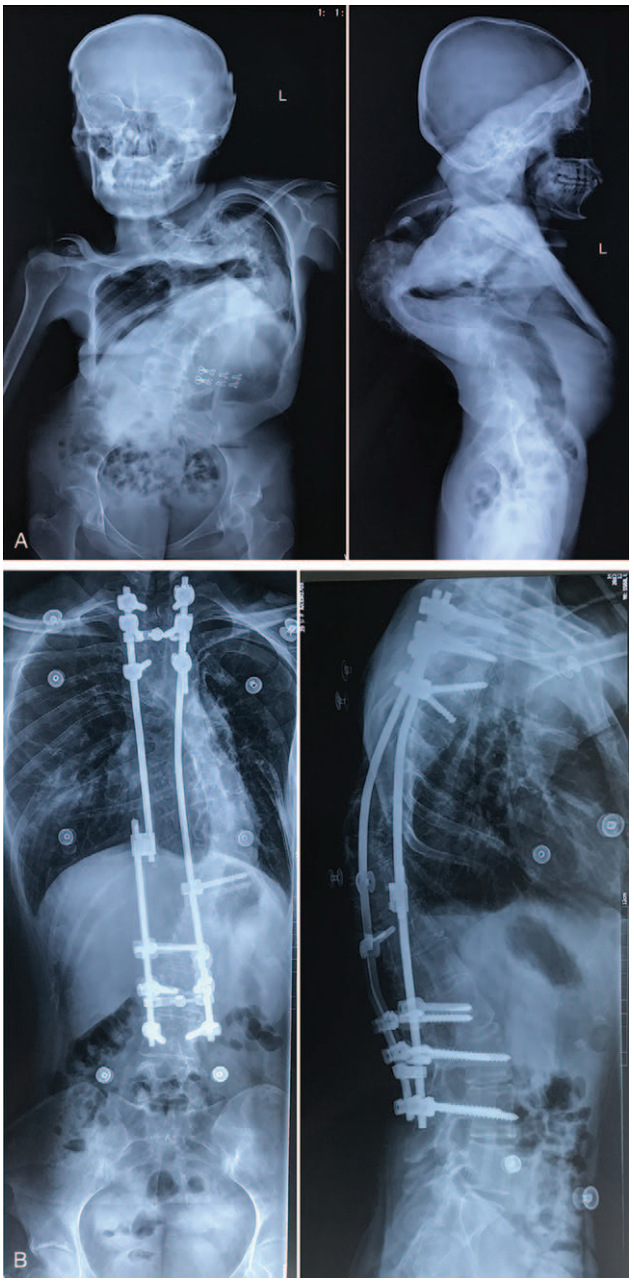

Figure 4. Anteroposterior and lateral plane of pre- (A) and post-treatment (B).

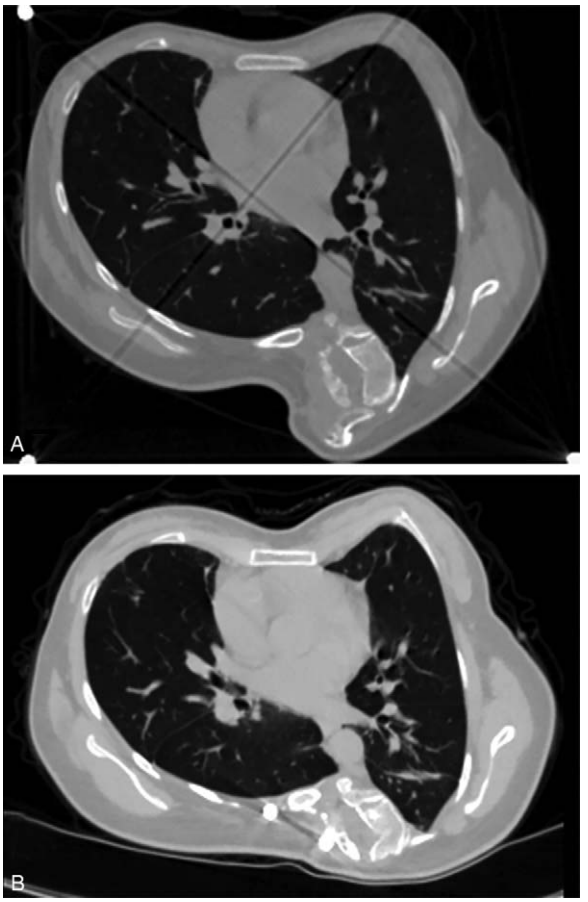

Figure 5. CT cross-section of thoracic cage. A. Preoperative image showed no lung tissue in rib hump deformity. B. Rib hump deformity was corrected, and no significant changes occurred to the thoracic cage.

severe respiratory impairment.[26] With the use of HPT, the main thoracic curve Cobb angle and kyphosis were reduced by 42.1% (namely, from 168.2°±14.28° to 97.3°±10.75°) and 40.5% (namely, from 159.4°±20.60° to 94.8°±9.58°), respectively, at the time of surgery. Moreover, this reduction was achieved without occurrence of neurological impairments. However, even after HPT, the thoracic curve remained rigid and the hunchback was obviously which might require osteotomy to achieve satisfactory outcomes.

We performed a modified thoracoplasty to achieve better rib hump deformity correction, despite the rigid and severe nature of the scoliosis. After our new thoracoplasty, the average height of rib hump was 15.3±3.4 mm, with the rib ends placed under the transverse process, with a correction rate of the rib hump deformity of 81.9%. This rate was higher than the rate of 44% to 65% previously reported for scoliosis correction combined with thoracoplasty.[2,4,27,28] Suk et al[2] reported a correction rate of rib hump height of 57% among 20 patients with AIS treated with thoracoplasty without direct vertebral rotation, and 70% among 30 patients of AIS treated with thoracoplasty and direct vertebral rotation. Yang et al[15] introduced a modified technique of thoracoplasty, the short apical rib resection thoracoplasty (SARRT), with a correction rate of the rib hump of 60.9%, compared with 44.4% after conventional thoracoplasty. The higher rate of correction achieved using our modified thoracoplasty technique might results from placing the rib ends under the transverse process. We do note, however, that all patients in our study group presented with severe vertebrae rotation, type V according to the Nash–Moe classification, and, as such, a small residual difference in the height of the ribs between the convex and concave sides might remain obvious.

According to the American Thoracic Society's guidelines for the severity of pulmonary impairment,[11] all 18 patients including in our case series were classified as having severe pulmonary impairment. When undertaking thoracoplasty in patients with severe pulmonary impairment, the concerns include complications during the perioperative period and the long-term impact of the surgery on pulmonary function. With regard to perioperative complications, 6 cases of pleural injury were

identified, with no severe complications associated with the surgery observed. Our results did show an improvement in FVC and FVC% at the last follow-up, from baseline, although this difference was not significant ($P > .05$). Previous studies have reported on the benefits of thoracoplasty combined with scoliosis in improving the PFTs among patients with AIS.[2,4,7,29,30] This improvement may result from an improvement in the mechanical environment for pulmonary function conferred by scoliosis correction.[4,31,32] However, a recent study specifically evaluated the specific effect of isolated thoracoplasty on the evolution of pulmonary function.[10] In this study, thoracoplasty was performed on the convex side, long after scoliosis surgery. Results revealed a decline in the FVC% of 9%, on average, among a group of 26 patients. Modifications in the chest-cage volume, respiratory muscle scarring, and postoperative pleural adhesions may have contributed to the declines in PFT values after thoracoplasty.[4]

5. Limitations

The limitations of our study need to be acknowledged. Foremost, the sample size was small. We also tried to perform a comparison of pre- and postoperative thoracic movement using the change in thoracic capacity between the inspiratory and expiratory phase to assess improvements in thoracic movement after the new thoracoplasty. However, the inspiratory and expiratory phases could not be easily distinguished, retrospectively, on the CT images, which may have led to error in our estimation of thoracic capacity.

6. Conclusions

In patients with severe and rigid scoliosis and severe pulmonary dysfunction, our modified thoracoplasty approach as effective and safety in achieving excellent razor back deformity correction without severe pulmonary complications. In addition, our modified thoracoplasty was not associated with any significant change in long-term pulmonary function. It is safe for correcting severe razor back in patients with severe thoracic scoliosis.

Author contributions

Conceptualization: Yijian Liang.
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Formal analysis: Bin Yu, Fei Wang.
Investigation: Bin Yu, Deng Zhao.
Methodology: Yijian Liang.
Software: Deng Zhao, Fei Wang, Rui Zhong.
Writing – original draft: Deng Zhao.
Writing – review & editing: Yijian Liang.

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