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The valuation of concave-side thoracoplasty on the treatment of extremely severe scoliosis with severe pulmonary dysfunction on the base of halo-pelvic traction

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Abstract

Extremely severe scoliosis patients, especially main thoracic Cobb' s angle >150°, often have severe thoracic deformity and pulmonary dysfunction, even the scoliosis is reduced by halo-pelvic traction, the improvement of pulmonary function is not satisfactory, the risk of spinal osteotomy in the next stage is still very high and left with obvious thoracic deformity. How to further improve the pulmonary function and appearance of these patients is a difficult problem to be solved.

Twenty extremely severe scoliosis patients with severe pulmonary dysfunction who underwent concave-side thoracoplasty in our hospital from September 2014 to September 2017 were included, data of thoracic volume and pulmonary function were collected before and after operation. The pulmonary function value reported was predicted forced vital capacity (FVC%), *T*-test was used to analyze the changes of the data by the statistical software SPSS21.0.

The 20 patient's averaged Cobb's angle of main thoracic was 163° ± 8° at admission and all of them with severe pulmonary dysfunction before concave-side thracoplasty. After operation, the thoracic volume of patients increased by 500.9 ± 222.9 mL, FVC % increased by 8.9% ± 7.5%. Both the difference has statistical significance ($P < .01$).

Concave-side thoracoplasty based on the halo-pelvic traction cannot only enlarge the volume of the concave thoracic cavity, lighten the compression of lung and further improve the pulmonary function of extremely severe scoliosis, but also can strengthen the correction of scoliosis and spinal rotation. Therefore, it is a safe and effective surgical approach.

Abbreviations: FVC = forced vital capacity, PFT = pulmonary function test.

Keywords: concave-side thoracoplasty, extremely severe scoliosis, halo-pelvic traction, pulmonary dysfunction, thoracic deformity

1. Introduction

Scoliosis is a complex and dynamic process that occurs in both the sagittal and coronal planes. Pain, neurological dysfunction from canal compromise, and coronal or sagittal malalignment are common clinical presentations. The convex prominence is often the noticeable problem of cosmetic concern to patients with severe scoliosis. Irreversible impairment of pulmonary function, even respiratory failure,[1] can occur in patients with extremely severe scoliosis. This has usually developed from an early onset scoliosis that did not get a prompt treatment.

Development of the technique of vertebral osteotomies, pedicle screw fixation systems and intraoperative neuromonitoring has contributed significantly to the advancement of scoliosis surgery, allowing the surgeon to obtain more correction in severe scoliosis.[2–4] However, it might be a significant challenge to treat patients with extremely severe scoliosis (Cobb's angle >150°), since they may not tolerate a complex and long surgical procedure with such a serious pulmonary dysfunction.[5–7] Staged surgical management has been used to treat severe scoliosis. Pre-operative traction including halo-gravity traction and halo-pelvic traction has demonstrated that it can be a useful method to decrease the scoliosis. During the traction, pulmonary function would improve significantly due to the decrease in scoliosis and

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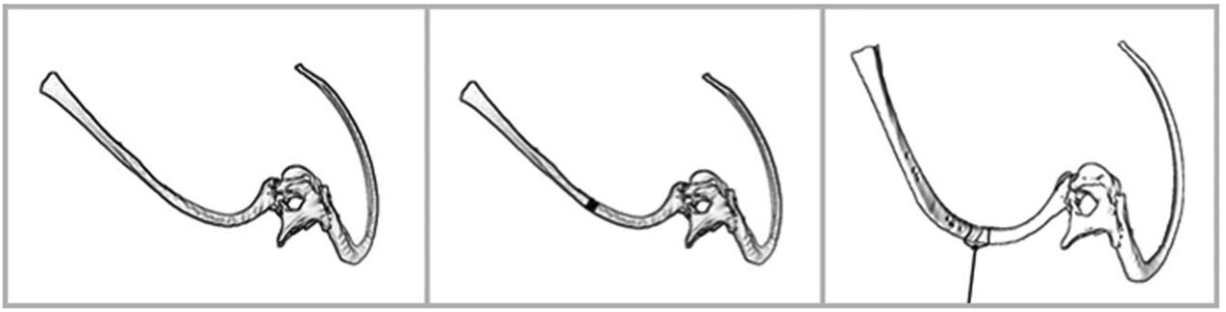

Figure 1. Surgery schematic Illustration of concave-side thoracoplasty, preoperative (A), intra-operative (B), and post-operative (C).

appropriate respiratory training. Unfortunately, not every patient would obtain an enough improvement in pulmonary function to tolerate surgical correction.

In this report, we presented a method of concave-side thoracoplasty based on halo-pelvic traction used to improve pulmonary function in patients with extremely severe scoliosis. Retrospectively analysis was performed to evaluate the outcomes of concave-side thoracoplasty.

2. Materials and methods

Since 2013, our department has tried to treat extremely severe scoliosis patients with a staging strategy by using halo-pelvic traction first, and then spinal osteotomy and pedicle screw fixation. But patients with extremely severe scoliosis usually combine with extremely respiratory dysfunction. After traction most patients can obtain a satisfied improvement in both spine curvature and respiratory function. But there are still some cases could not get enough improvement in respiratory function to tolerant spinal surgical correction. Then concave-side thoracoplasty was designed. Concave-side thoracoplasty was offered to patients with severe depression of the concave thoracic cage who had been treated with halo-pelvic traction. The indication of the operation was that patients with extremely severe scoliosis that did not obtain a satisfactory improvement in pulmonary function, and could not tolerate the spinal osteotomy. Twenty patients with extremely severe scoliosis (the main thoracic Cobb's angle $>150°$ that underwent concave-side thoracoplasty in our hospital were retrospectively reviewed from September 2014 to September 2017. The data recorded included thoracic volume and pulmonary function test before and after concave-side thoracoplasty. A Philips 64-row Spiral CT was used to take images of thoracic cage. Pulmonary function was measured using a Master Lab pulmonary function instrument. According to the American Thoracic Society's guidelines for the severity of pulmonary impairment, no pulmonary impairment was considered an FVC% $>$ 80%, mild impairment was an FVC% of 65% to 80%, moderate impairment was an FVC% of 50% to 65%, and severe impairment was an FVC% $\leq$ 50%. So the percentage of the predicted value (FVC%) of pulmonary function test (PFT) were used to evaluate the influence of pulmonary function.[5] Patients were excluded in the presence of any of the following scenarios:

1. patients with the lung disease or other diseases that might impair pulmonary function;
2. patients without complete data.

As a retrospective study, we did not mention any personal information of any patient which might be free for ethical approval.

2.1. Operative procedures

Patients were positioned prone on a surgical table and a posterior longitudinal incision located about 2 to 4 cm inside the scapular line was taken. The 7th to 12th ribs were exposed through the incision and were subperiosteally stripped over 4 to 8 cm. The exposed ribs were cut. And both sides of the broken ends of each rib were fixed together using a forceful suture. The forceful sutures were pierced the skin and suspended on the rod of apparatus of halo-pelvic traction (Figs. 1 and 2,). A regularly scheduled traction of the depressed ribs through the sutures was performed each week. During the traction, all the patients underwent respiratory training, such as deep respiration and balloon exercise. When the broken ends of the ribs were fused and fixed, and the thorax was stabilized, the sutures were removed (Fig. 3). The traction time of the ribs was usually 4 months.

2.2. Statistical methods

Statistical analysis was performed using the statistical software SPSS 21.0. A *T*-test was used to analyze the data before and after the operation, with $P < .05$ indicating that the difference had statistical significance.

3. Results

All 20 patients presented with extremely severe scoliosis with a minimum main thoracic curve Cobb's angle more than 150° and severe pulmonary dysfunction. The mean age of the 20 patients was 24.5 ± 6.0 years old (range from 14 to 35 years old). There were 10 females and 10 males. The average Cobb's angle of the main thoracic curve was $163 \pm 8°$ at admission. The FVC% was $44.6\% \pm 10.6\%$ before concave-side thoracoplasty. The average time of rib-traction was 116 ± 15 days. During this period of concave-side thoracoplasty, no patients had complications such as pleural rupture, pleural effusion, respiratory failure, and so on. There were four patients with an incision infection, all of which were cured by drug treatment.

After the treatment, the thoracic volume, FVC% retrospectively increased 500.9 ± 222.9 mL, $8.9\% \pm 7.5\%$ (Table 1). The patients' pulmonary function and appearance were further improved (Figs. 4 and 5,). There was a statistically significant

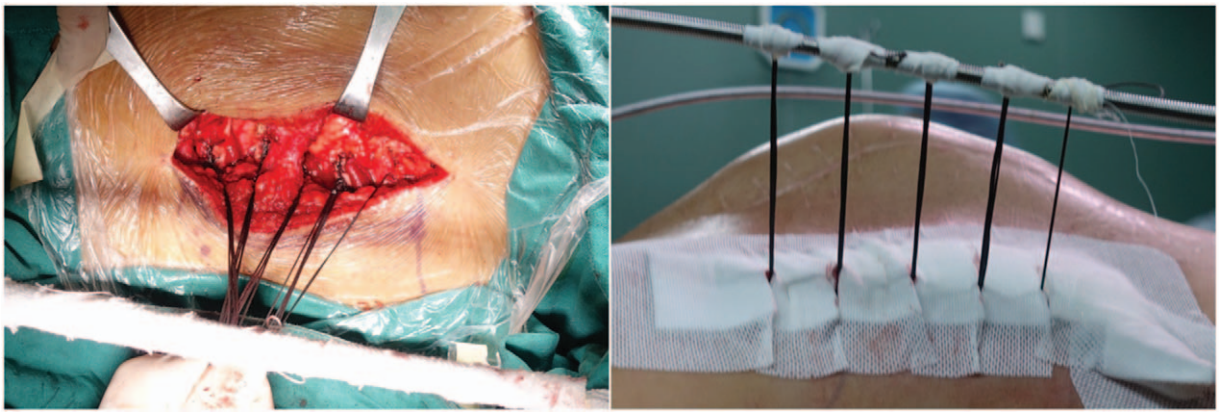

Figure 2. Illustration of surgical procedure. (A) Cut the most depressed ribs and pull up the broken ends with tendon sutures. (B) Fix the broken ends of ribs on the rod of halo-pelvic traction by tendon sutures and make a persistent traction of the depressed ribs.

difference between pre- and post-operative outcomes ($P < .05$) for all data recorded.

4. Discussion

In patients with untreated scoliosis, it has been reported that the mortality is much higher than normal people, and the main causes of death were respiratory failure and cardiovascular disease. The influence of scoliosis on pulmonary function is mainly due to the limitation of lung volume caused by thoracic deformity following thoracic scoliosis. Previously it has been reported that the thoracic volume during the inspiratory phase and expiratory phase in scoliosis patients were both lower than those in normal controls.[8] In addition, the level of respiratory impairment had a positive correlation with the severity of the scoliosis, especially thoracic and/or thoracolumbar scoliosis.[9,10]

Figure 3. 3D CT images of fusion of the broken rib ends.

Qiu Yong[11] found that there was a significant negative correlation between Cobb's angle and FVC%. When the Cobb's angle $> 70°$, the patient's pulmonary function presents with typical restrictive ventilation dysfunction, and when more than 100°, obstructive ventilation dysfunction. In some serious cases, small airways were distorted, which may lead to pulmonary hypertension and pulmonary heart disease.[12]

For patients with extremely severe scoliosis and extremely severe respiratory impairment, to undergo a surgical treatment is a huge challenge to surgeons and anesthetists. The development of scoliosis would aggravate the respiratory impairment. For patients with severe scoliosis, internal fixation of the spinal column without correction might result in an early failure.[6] Since 2013, our department has tried to treat extremely severe scoliosis patients with a staging strategy by using halo-pelvic traction first, and then spinal osteotomy and pedicle screw fixation. During the traction, pulmonary function would improve because of the improvement of scoliosis and respiratory training. Subsequently, a spinal osteotomy could then be performed. Most patients could obtain a satisfactory outcome. Unfortunately, not every patient would obtain enough improvement in pulmonary function to tolerate surgical correction after the traction.

As we know, thoracic deformity is the major factor affecting the pulmonary function of patients with scoliosis.[13] However, at present the treatment of thoracic deformity is mainly focused on the convex side (rib hump resection[14,15]), and the concave side has been rarely reported. But for these patients, the concave depression of the thoracic spine is the main contributor of respiratory impairment.[6,16,17] When treating the convex side only it is difficult to obtain a satisfactory appearance and

Table 1

Changes of the data of TV, VC, FVC% and self-image score before and after concave-side thoracoplasty.

Parameter	Preoperative (n = 20) Mean ± 1 SD	postoperative (n = 20) Mean ± 1 SD	*P*-Value
TV (mL)	2128.0 ± 803.7	2629.7 ± 785.4	<.01
VC (mL)	1754.5 ± 684.9	1984.0 ± 672.7	<.01
FVC%	44.6% ± 10.6%	53.5% ± 11.0%	<.01

According to the American Thoracic Society, FVC ≤ 50% were severe pulmonary dysfunction.
FVC% = percent predicted forced vital capacity, TV = thoracic volume, VC = vital capacity.
$P < .01$ indicates that the difference has significant statistical significance.

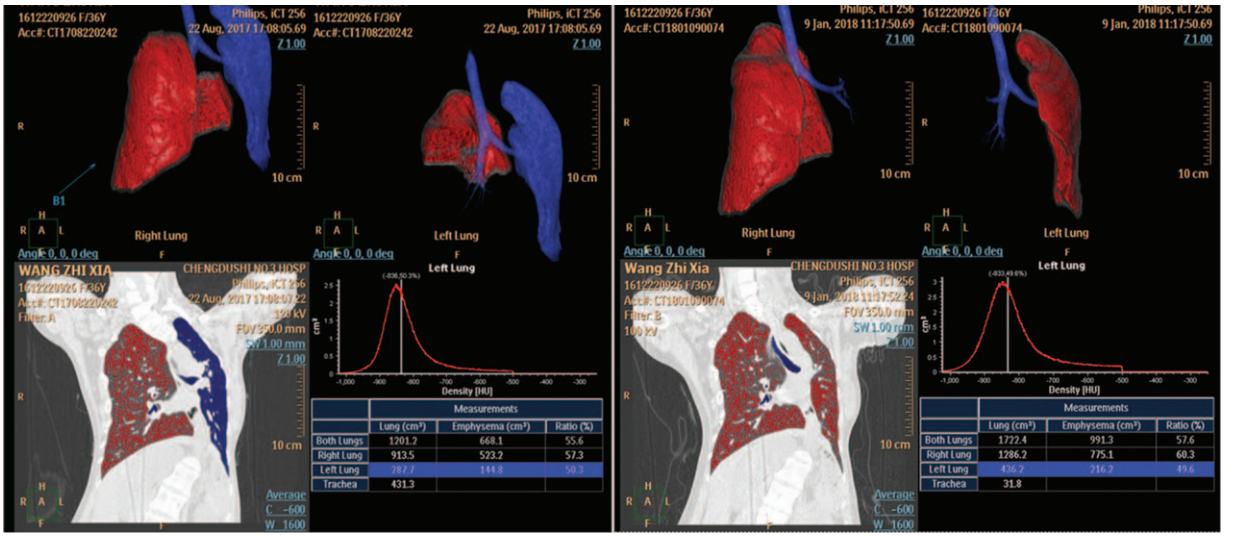

Figure 4. Changes of vital capacity (VC) before and after concave-side thoracoplasty. Thoracic volume of the patient was 1201.2 mL preoperatively (A) and 1722.4 mL postoperatively (B), which increased by 521.2 mL.

pulmonary functional improvement, and current studies show that pulmonary function will be further damaged in the short term after the rib hump resection.[18–21] Some studied in rabbit model showed that expansion thoracoplasty in concave side can interrupt progression of deformity and pulmonary hypoplasia in severe initial deformity, but only apparent in cases of severe juvenile deformity.[22] These studies described that expansion thoracoplasty might be one chance for patient with severe scoliosis to improve pulmonary function. An expansion thoracoplasty might be the only way for patients who did not obtain a satisfied improvement of pulmonary function after halo-pelvic traction. After sufficient communication with these patients, concave side thoracoplasty was performed. Fortunately the result was good that pulmonary function improved.

For patients with extremely severe scoliosis, the ribs become thin and straight, and lose their normal curvature because of spinal rotation and scoliosis. It can cause a severe decrease in thoracic volume and limit the movement of the thorax. Moreover, we find that the most depressed ribs on the concave side are usually the 7th to 10th ribs, which mainly support the middle and lower lungs, and are the most important part of lung ventilation function.[23] These patients are often accompanied by very serious pulmonary dysfunction at admission. Even with the scoliosis reduced gradually by halo-pelvic traction, the improvement of respiratory function showed a ceiling effect during the traction. For the FVC%, it was still difficult to reach the expected value of 50%. Consequently, the risk in the next treatment of spinal osteotomy, which might last several hours, was still too high.

In order to solve the problem, we tried to treat these patients with thoracoplasty on the concave side based on the characteristics of halo-pelvic traction in our patients to enlarge the volume of the concave thorax and further improve pulmonary function. The method was first reported by Tian in 2009,[24] Who was the

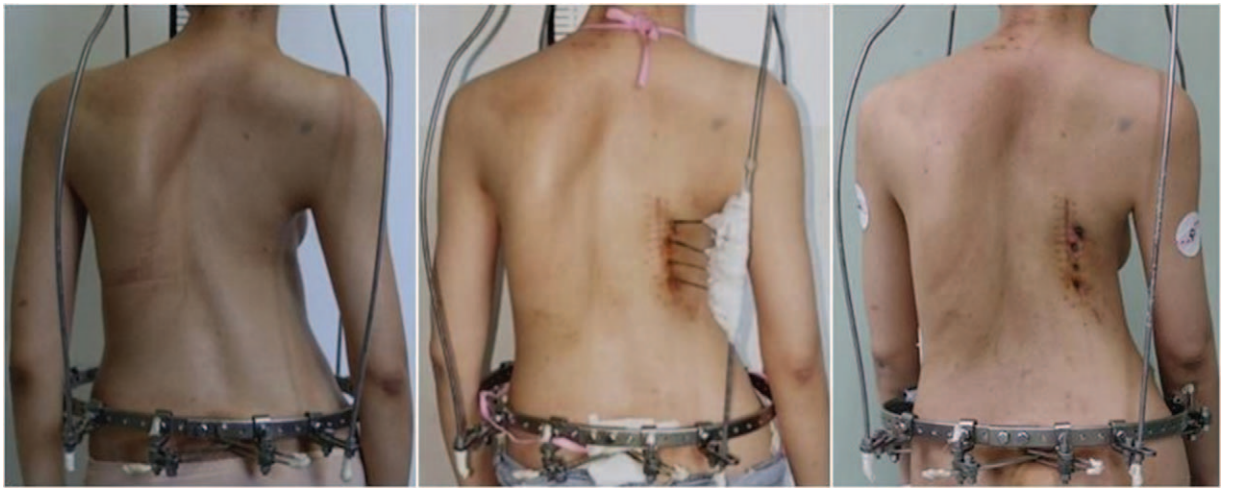

Figure 5. Changes of patient's appearance before and after concave-side thoracoplasty preoperative (A), traction of the depressed ribs (B), and post-operative (C).

first to compare the pre- and post-operative data of parameters including thoracic volume, FVC, FVC% to evaluate the value of the operation in patient with extremely severe scoliosis. Unfortunately, no data including thoracic volume, FVC, or FVC% was mentioned either before or after the operation.

In our study, the concave-side thoracic curve was reduced. More importantly, the thoracic volume increased 500.9 ± 222.9 mL, and FVC% increased from 44.6% + 10.6% preoperatively to 53.5% + 11.0% postoperatively. While FVC% has been shown to decline significantly by 9% after thoracoplasty on the convex side 25, the FVC% increased 8.9% after concave-side thoracoplasty in our study. This meant that the patient's pulmonary function was further improved after the ceiling effect, and decreased the risk of pulmonary complication during the preoperative period. There was a report that showed scoliosis patients with a history of chronic lung disease and undergoing fusion of 8 or more segments may be at an increased risk for reintubation, which was an independent risk factor for inpatient mortality. In the period of concave-sided thoracoplasty (the average treatment time of rib traction was 116 ± 15 days), no thoracic complications occurred, such as pleural rupture, pleural effusion or pulmonary infection. Four patients suffered incision infections and all of them were cured by drug treatment.

From the results presented, the procedure is safe and useful for patients with extremely severe scoliosis and severe pulmonary dysfunction. What is more, it utilizes our patient's own characteristic, based on the halo-pelvic traction device. This device made a transversal traction of the concave ribs, which could provide a convenient condition for recovery of a collapsed chest. It can not only enlarge the volume of the concave thoracic cavity, lighten the compression of lung and further improve the pulmonary function of patients, but also can strengthen the correction of scoliosis and spinal rotation. Therefore, it is a safe and effective surgical approach.

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Author contributions

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Writing – review & editing: Yijian Liang.

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