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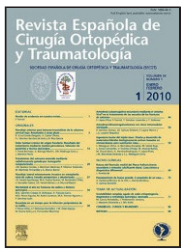

ORIGINAL ARTICLE

Effect of thoracoplasty on pulmonary function and esthetics in patients with adolescent idiopathic scoliosis

J.M. Sánchez-Márquez*, N. Fernández-Baillo, A. García-Fernández, J. Quintáns and F.J. Pérez-Grueso

Orthopaedic Surgery and Traumatology department, University Hospital of La Paz. Madrid, Spain

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KEYWORDS
Adolescent idiopathic scoliosis;
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Abstract
Purpose: To evaluate pulmonary function and clinical and functional outcomes in patients with adolescent idiopathic scoliosis (AIS) treated with posterior spinal fusion and costoplasty.
Materials and methods: We evaluated prospectively 18 consecutive patients with thoracic AIS treated with instrumented posterior spinal fusion with concomitant costoplasty with a 2 years follow-up. Pulmonary function was assessed by forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) before surgery, and one and two years after surgery. We used the SRS-22 questionnaire to assess the clinical outcomes before surgery and two years after surgery.
Results: Average absolute preoperative FVC was 2.63 L (theoretical predictive value FVC: 77.15%) while FEV_1 was 2.29 (theoretical predictive value FEV_1: 79.46%). At one year postsurgery, mean values of FVC and FEV_1 were, respectively, 2.77 and 2.48 (theoretical predictive value FVC: 79.8% and FEV_1: 85.2%). At two years postsurgery, mean value of FVC was 2.86 L and 2.64L for FVC and FEV_1 respectively, that is, FVC: 81.8%, and FEV_1: 89.15%. The improvement in the self-image item of the patients after surgery on the SRS-22 questionnaire is very significant.
Conclusions: The pulmonary function tests show that these scoliotic patients have a significant progressive improvement of FVC and FEV_1 at one and two years postsurgery, compared with the preoperative values.

*Corresponding author.
E-mail: jm.sanchez.marquez@gmail.com (J.M. Sánchez-Márquez).

PALABRAS CLAVE
Escoliosis idiopática del adolescente;
Función respiratoria;
Costoplastia

Efecto de la costoplastia en la función pulmonar y la estética en pacientes con escoliosis idiopática del adolescente

Resumen
Objetivo: Evaluar en pacientes con escoliosis idiopática del adolescente, intervenidos mediante artrodesis vertebral posterior y costoplastia, la función pulmonar y los resultados clínicos y funcionales.
Material y método: Evaluamos prospectivamente a 18 pacientes consecutivas con escoliosis idiopática del adolescente con componente torácico, a las que se les realizó artrodesis vertebral posterior instrumentada con costoplastia asociada, con un seguimiento de 2 años. La función pulmonar se valoró por medio de la capacidad vital forzada (CVF) y el volumen espiratorio máximo en el primer segundo (VEM1) en la espirometría basal preoperatoria, al año y a los 2 años postoperatorios. Para la evaluación clínica y funcional se utilizó el cuestionario SRS-22, preoperatorio y a los 2 años de la cirugía.
Resultados: La CVF preoperatoria media fue de 2,63 l (77,15% del valor teórico), mientras que el VEM1 medio fue de 2,29 l (79,46% del valor teórico). Los valores medios al año postoperatorio fueron de 2,77 l para la CVF y de 2,48 l para el VEM1 (un 79,8 y un 85,2% de los valores teóricos, respectivamente). A los 2 años postoperatorios, el valor medio de la CVF fue de 2,86 l y del VEM1 de 2,64 l, es decir, un 81,8 y un 89,15% de los valores teóricos, respectivamente. Resultó muy significativa la mejoría en la percepción de la autoimagen del paciente tras la cirugía.
Conclusiones: Las pruebas funcionales respiratorias demuestran que los pacientes escolióticos intervenidos experimentaron una mejoría significativa y progresiva de la función respiratoria con respecto al control basal prequirúrgico.

Introduction

The objectives for surgical treatment of patients with scoliosis are to achieve a stable and equilibrated spine and to avoid curve progression, with maximum correction of the deformity and minimum vertebral fusion. It is of particular importance to the patients the aesthetic quality of their torso due to the rib hump, which can be the source of considerable pain, functional limitation in the ribcage, and cause for a negative self-image in patients with scoliosis.

Traditional instrumentations have exerted distractive force in order to correct scoliosis, but have had little effect on the rib hump, for which surgeons have resorted to costoplasty in order to correct the thoracic deformity provoked by the convex prominence of the ribs. With new instrumentations, surgeons can exert a bar derotation with direct vertebral rotation and translation, which has greater corrective power on the rib deformity. In spite of these instrumentation improvements, costoplasty still contributes a major improvement of the residual rib deformity following scoliosis reduction.[1]

According to the medical literature, the corrective surgical effect of costoplasty on the pulmonary function of patients with idiopathic scoliosis is variable. Studies exist that show that costoplasty associated with surgical correction of scoliosis negatively affects pulmonary function,[2-4] as evaluated by the parameters of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). However, other studies have shown no measurable changes in pulmonary function following surgery, and even, in some cases, an improvement.[1,5,6] This controversy surrounding the effects of rib hump corrections using costoplasty on pulmonary function can be attributed to the lack of homogeneity of groups in different studies due to age, spinal curvature, severity of the curvature, severity of the rib hump, and the type of instrumentation used.

The objective of our study was to analyse costoplasty as a valid option for aesthetic correction of rib humps. To this end, we studied a homogenous population with adolescent idiopathic scoliosis (AIS) with a thoracic component, in order to evaluate the effect of costoplasty associated with instrumented posterior spinal fusion on pulmonary function and aesthetic quality of the patients.

Patients and methodology

We prospectively evaluated 18 consecutive female patients with AIS with a thoracic component, which were intervened at our institution through instrumented posterior spinal fusion and associated costoplasty. We analysed corrections of spinal curvature and rib hump through surgery, and the functional result through comparisons of preoperative state and progress at 2 years after the intervention with the SRS-22 questionnaire. We measured pulmonary function using preoperative FVC and FEV1 values and at one and two years following surgery.

All of the patients were adolescent girls with a mean age of 14 years (range: 12-18) at the time of surgery, and follow-up time was a minimum of 2 years. Preoperative and

postoperative standing radiographs were taken of the sagittal and coronal planes using the Cobb method. We used a Cobb angle from T3 to T12 in order to measure thoracic kyphosis, and the T12 to S1 angle to measure lumbar lordosis.

According to the Lenke classification system,[7] 9 patients presented a type 1 curve (1st = 6, 1B = 1 and 1C = 2), 7 patients presented a type 2 curve (2nd = 5, 2B = 1 and 2C = 1), and 2 patients presented a type 3 curve (both were 3C). The patients with primary thoracolumbar or lumbar curvatures were excluded from this study and none of the patients had received a previous surgical intervention on the spine.

All of the patients were subjected to functional respiratory tests to evaluate pulmonary function before the surgery and at 1 and 2 years post-operation. These tests were performed on the sitting patient, taking the highest value of three attempts. The parameters measured were FVC and FEV1 in absolute values, as well as the percentage of the theoretical value predicted from arm width (as an estimation of height corrected for age). In contrast with other authors,[3,5] we did not evaluate pulmonary function at 3 months in order to avoid the confusing variable that postoperative pain during spirometry can create.

The rib hump was clinically measured with the help of a scoliometer, as the patient inclined forward. All patients presented a preoperative rib hump greater than 10°.

Clinical and functional evaluations were performed using the SRS-22 questionnaire, before and 2 years after the surgery.

Surgical technique

The same surgical team performed all of the procedures using hybrid instrumentation. Fusion was performed from the proximal region of the superior edge of the vertebra to the caudal region of the inferior vertebral edge. Type 1 Lenke curvatures were treated with selective fusion, while type 2 and 3 curvatures received fusion of both curves.

The decision to perform a costoplasty, as well as the number of ribs to be resected, was made following reduction of the residual functional deformity of the rib hump. We used the technique described by Steel,[8] in which the periosteum of the rib was carefully dissected in order to avoid damage to the parietal pleura, and the osteotomy was initiated as far as possible from the vertebral body (ending at the posterior axillary line). Haemostasis of the rib ends was achieved using Gelfoam® or bone wax.

Statistical analyses were performed using the SPS statistical program, using Friedman and Wilcoxon tests for repeated variables; we considered values to be statistically different at a p value < 0.05.

Results

We achieved a significant correction of the curvatures (table 1); mean preoperative Cobb angle values for proximal thoracic curvature was 43.33°, while the mean value

Table 1 Radiographic results: comparison between preoperative and postoperative angle values in coronal and sagittal planes using the Cobb angle

Curve	Preoperative	Postoperative
Proximal thoracic	43.33° (23-65)	18.5° (12-30)
Principal thoracic	67.55° (50-90)	24.16° (10-41)
Thoracolumbar-lumbar	45,46° (20-72)	21.26° (4-40)
Thoracic kyphosis	23.86° (0-45)	21.22° (6-45)
Lumbar lordosis	56.75° (35-80)	46.88° (30-64)

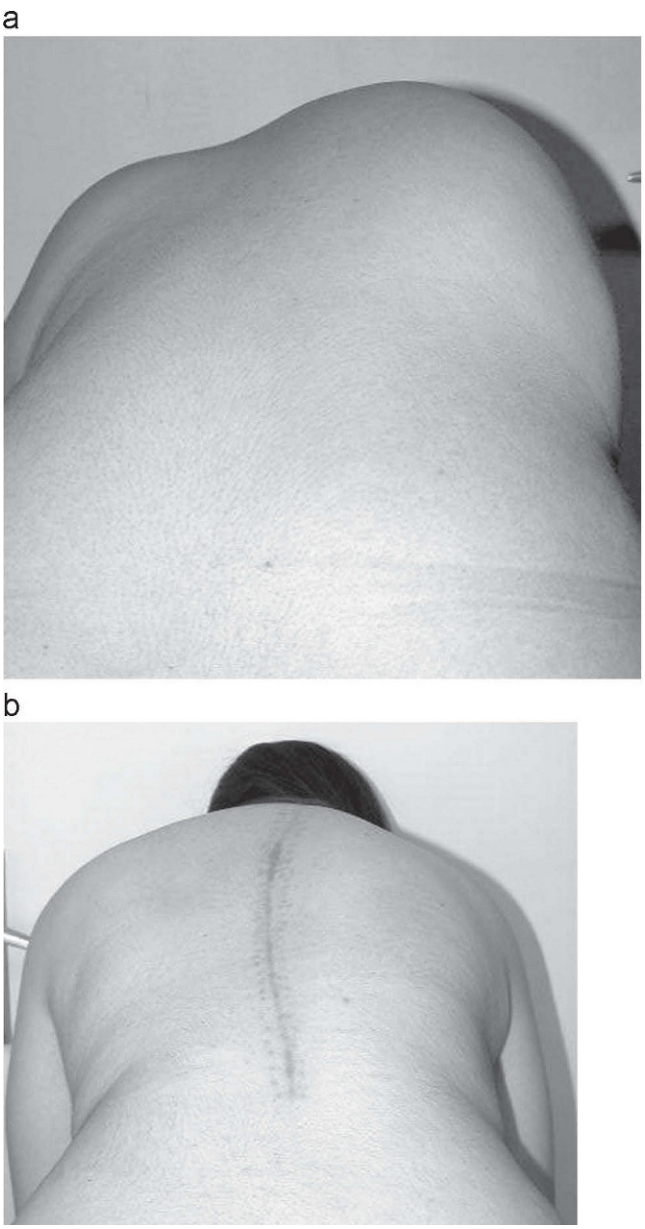

Figure 1 a) Preoperative image of a patient with idiopathic adolescent scoliosis. b) Postoperative image of a patient with adolescent idiopathic scoliosis, displaying the rib hump correction following posterior vertebral arthrodesis and an associated costoplasty.

immediately post-operation was 18.5°. The principal thoracic curvature was corrected from a mean value of 67.55° before the surgery to 24.16° following reduction and arthrodesis. The thoracolumbar-lumbar curve was reduced by over 50%, from 45.46° preoperative to 21.26° postoperative.

The modification of the sagittal profile was not as prominent: mean preoperative thoracic kyphosis was 23.86°, while postoperative values averaged 21.22°. Mean preoperative lumbar lordosis was 56.75°, while postoperative values averaged 46.88°.

Mean preoperative rib hump angle (fig. 1) was 16.26°, reaching a mean value of 5.24° ($p = 0.001$) at the end of the follow-up period. The mean number of ribs implicated in the costoplasty was 4 (range: 3-5), with the seventh and tenth convex ribs being the most frequent. Only 2 of the 18 patients required a chest tube immediately after the operation.

The changes in mean pulmonary function values are shown in table 2. The postoperative FVC and FEV1 value improvements were statistically significant and even higher than the theoretical value that had been estimated of 77.15, 79.82 and 81.88% for FVC, and 79.46, 85.2 and 89.15% for FEV1 before surgery, at 1 year, and at 2 years after surgery, respectively. The increase in absolute values was also statistically significant; the mean preoperative FVC value was 2.63 l, 2.77 l at one year, and 2.86 l at two years. Mean absolute FEV1 values passed from 2.29 l preoperatively to 2.48 l at one year and 2.64 l at two years after surgery.

The mean values on the clinical-functional SRS-22 scale are displayed in table 3. Quality of life values improved significantly ($p = 0.001$), with a mean preoperative value of 4 and at 2 years post-operation: 4.40. Upon independent analysis of each item, we observed that the main increase was due to self-image, which improved from a mean value of 2.9 in the preoperative survey to 4.28 at 2 years after the surgery ($p = 0.001$).

Three cases of floating chest (fig. 2) were produced during this study as a secondary process to excessive rib resection with a paradoxical movement during respiration, that is, collapse of the ipsolateral hemithorax during inspiration. In 2 patients, lesions were produced in the parietal pleura during costoplasty, which required sutures and a chest tube. The tubes were left in place for 3 to 5 days, and had no effect on the final result.

Table 3 Clinical and functional results (Mean values of the preoperative SRS-22 and at 2 years after surgery)

SRS-22	Preoperative	2 years after surgery
Function/activity	4.46	4.32
Pain	4.32	4.65
Self-image	2.92	4.27
Mental health	4.22	4.35
Subtotal	*4*	*4.4*
Satisfaction		4.6
Total		*4.43*

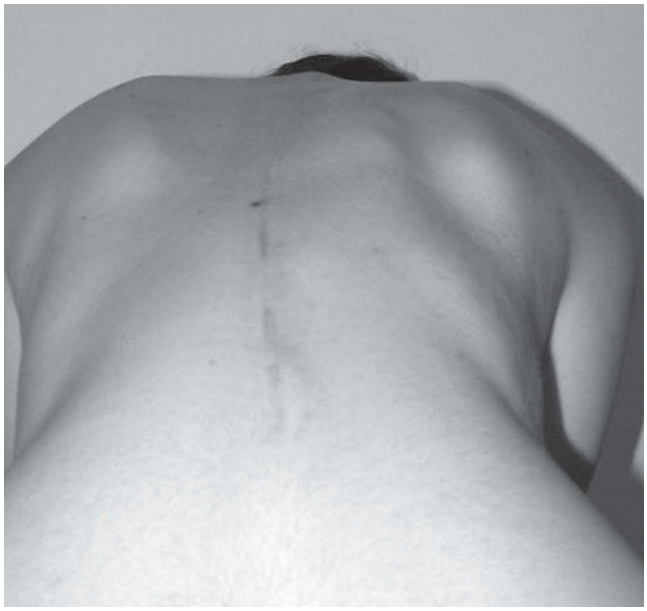

Figure 2 Patient image of a floating chest. Note the collapse of the right hemithorax during inspiration.

Table 2 Pulmonary function tests: preoperative evaluation, at 1 year, and at 2 years after the surgery, examining forced vital capacity and forced expiratory volume in 1 second in absolute values and as percentages of estimated theoretical errors

Pulmonary function	Preoperative	1 year postoperative	2 years postoperative
FVC			
Absolute (l)	2.63 (1.72-3.62)	2.77 (2.27-3.87)	2.86 (2.07-3.59)
Predicted, %	77.15 (59.2-114.4)	79.82 (54-126.3)	81.88 (58.1-128.9)
FEV1			
Absolute (l)	2.29 (1.76-2.61)	2.48 (2.09-3.23)	2.64 (2.06-3.5)
Predicted, %	79.46 (54.2-112.2)	85.20 (61.8-129.1)	89.15 (65.5-137.8)

FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second.

Discussion

Scoliosis is a tridimensional deformity of the spinal column and rib cage, with a lateral curvature in the transverse plane. In convex thoracic scoliosis, the ribs are displaced and rotated posteriorly, and the coronal diameter of the chest cavity is reduced. In concave thoracic scoliosis, the ribs are displaced and rotated anteriorly, with reduction in the sagittal diameter of the rib cage.[1,5] These conditions provoke compression of the pulmonary parenchyma and the airway, with a reduced pulmonary volume and airflow. This detriment to pulmonary function is directly related with the severity of scoliosis, thoracic hypokyphosis, and age.[1,2,4]

Although scoliosis surgery is usually performed to correct the curvature of the coronal plane, patients show greater concern for the thoracic deformity and rib hump;[5] as such, if no positive correction of the rib hump is achieved, even though a good correction of the scoliosis may have occurred, patients show less satisfaction with the surgical results.

Rib resection in the convexity of the thoracic curvature associated with posterior instrumented vertebral arthrodesis is a valid option for improving the aesthetic results of scoliosis correction, as well as providing a source for an autograft.

Traditional Harrington instrumentation uses a distractive force to correct scoliosis with little effect on the rib cage. The effect of this instrumentation on pulmonary function has been studied with uneven results, varying from improvement to decrease in FVC and FEV1.[5,9] This controversy can be attributed to the lack of homogeneity in the population studied. With the introduction of new systems of instrumentation and methods for correcting the deformity, a tridimensional correction of scoliosis can be achieved, such that translation and derotation can be achieved without the need for associated costoplasties, yielding a 22 to 37% reduction of the rib hump.[1,10]

Several studies have evaluated the results in instrumented posterior vertebral arthrodesis associated with costoplasty. Geissele et al[10] obtained a mean correction of the rib hump of 71% upon vertebral fusion and costoplasty. Min et al[6] achieved a 44% reduction in the rib hump, while Suk et al[1] achieved a 66% final reduction. In our study, rib hump went from a mean preoperative value of 16.26° to 5.24° at the end of the follow-up period, implying a 67% reduction. When the reduction in the rib hump is compared to the hump in patients who have received a reduction and arthrodesis, with and without associated costoplasty, we see that hump correction is greater when performed together with costoplasty.[1]

Other studies have centred on evaluating pulmonary function through posterior instrumentation and associated costoplasty in AIS. Chen et al[5] and Steel[8] published on a reduction in pulmonary function at 3 months after surgery, but at one year, recovered preoperative values. When, on top of the posterior instrumentation and costoplasty, a thoracoscopic anterior release was associated with the procedure, the pulmonary function tests did not reach the preoperative values. Kim et al[2] observed no changes in absolute FVC and FEV1 values following the posterior vertebral arthrodesis and costoplasty, but did show changes in the percentages of estimated values at the 2 year follow up. Lenke et al saw a decrease in pulmonary function at 3 months following the surgery in 16% of adolescents and 27% in adults, but these returned to preoperative values in the first group at 2 years, while values in adults remained at 23% below the preoperative values at 2 years.

Our study produced an improvement in the spirometric parameters of pulmonary function, both expressed as percentages of estimated values, and as an absolute value, with statistical significance at 2 years with respect to the preoperative values. We did not perform respiratory function tests at 3 months following the intervention in order to avoid the input of a possible confounding factor that could produce post-surgical pain during spirometry.

Few studies compare clinical and functional results in patients who have received an instrumented posterior vertebral fusion with and without associated costoplasty. Suk et al[1] showed no statistically significant differences in mean SRS-30 scores between patients that had received posterior arthrodesis with and without associated costoplasties. However, they did find significant differences in self-image, obtaining a higher score in the group of costoplasties associated with arthrodesis. In our study, the clinical and functional improvements as measured using the SRS-22 document after surgery were statistically significant, especially with regard to self-image.

In conclusion, costoplasty associated with instrumented posterior vertebral arthrodesis has no negative effect on pulmonary function, shows a progressive postoperative improvement in the spirometric parameters, and achieves a significant correction in the rib hump and self-image of the patient. Prospective studies with similar patients to those included in our study would be of special interest, but as a 2 group comparison, one with a posterior arthrodesis and associate costoplasty, and the other with a posterior arthrodesis but without an associated costoplasty, in order to evaluate the effect of costoplasty on pulmonary function and aesthetic quality as isolated variables.

Conflict of interest

The authors affirm that they have no financial, institutional, or personal relationship that could lead to a conflict of interests with relation to this article.

References

1. Suk S, Kim SH, Kim SS, Lee JJ, Han YT. Thoracoplasty in thoracic adolescent idiophatic scoliosis. Spine. 2008;33:1061-7.
2. Kim YJ, Lenke LG, Bridwell KH, Kim KL, Steger-May K. Pulmonary function in adolescent idiopathic scoliosis relative to the surgical procedure. J Bone Joint Surg (Am). 2005;87-A:1534-41.
3. Vedantam R, Lenke LG, Bridwell KH, Haas J, Linville DA. A prospective evaluation of pulmonary function in patients with adolescent idiopathic scoliosis relative to the surgical approach used for spinal arthrodesis. Spine. 2000;25:82-90.
4. Lenke LG, Bridwell KH, Blanke K, Baldus C. Analysis of pulmonary function and chest cage dimension changes after thoracoplasty in idiopathic scoliosis. Spine. 1995;20: 1343-50.

5. Chen SH, Huang TJ, Lee YY, Hsu RW. Pulmonary function after thoracoplasty in adolescent idiopathic scoliosis. Clin Orthop Relat Res. 2002;399:152-61.
6. Min K, Waelchli B, Hahn F. Primary thoracoplasty and pedicle screw instrumentation in thoracic idiopathic scoliosis. Eur Spine J. 2005;14:777-82.
7. Lenke LG, Betz RR, Harms J, Bridwell KH, Clements DH, Lowe TG, et al. Adolescent idiopathic scoliosis: A new classification to determine extent of spinal arthrodesis. J Bone Joint Surg (Am). 2001;83-A:1169-81.
8. Steel HH. Rib resection and spine fusion in correction of convex deformity in scoliosis. J Bone Joint Surg (Am). 1983;65:920-5.
9. Upadhyay SS, Gunawardene WMS, Leong JCY, Hsu LCS. Change in residual volume relative to vital capacity and total lung capacity after arthrodesis of the spine in patients who have adolescent idiopathic scoliosis. J Bone Joint Surg (Am). 1993;75-A:46-52.
10. Geissele AE, Ogilvie JW, Cohen M. Thoracoplasty for the treatment of rib prominence in thoracic scoliosis. Spine. 1994;19:1636-42.