COSTOPLASTY IN ADOLESCENT IDIOPATHIC SCOLIOSIS

OBJECTIVE RESULTS IN 55 PATIENTS

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Costoplasty can reduce the important cosmetic deformity of rib prominence in scoliosis but there are few objective reports of correction. We recorded the results of three objective methods of assessing back shape before and after short-segment costoplasty in 55 patients. We showed that significant improvement was maintained over a two-year follow-up period. Primary costoplasty at the time of scoliosis surgery (n = 35) achieved greater proportional correction than secondary costoplasty performed after fusion of the spine (n = 20). The rib segments removed at primary surgery provided enough bone for the autogenous graft; harvesting from the pelvis was unnecessary.

We report a new classification of rib morphology which helps in planning the site and extent of costoplasty, and in predicting the possible correction.

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The unilateral rib prominence often seen in adolescent idiopathic scoliosis is frequently the main concern of the patient, and may cause social and psychological damage (Clayson and Levine 1976). Rib prominence on the convex side results from vertebral rotation.

The aims of operation are to prevent progression of the scoliosis and to improve appearance, but posterior instrumentation does not fully correct vertebral and rib rotation (Benson, De Wald and Schultz 1977; Aaro and Dahlborn 1982). The rib prominence may even be increased by the reduction of lateral curvature with

Harrington instrumentation (Weatherley et al 1987). In the immature spine, even after posterior fusion, vertebral rotation may worsen although lateral curvature remains constant (Hefti and McMaster 1983; Edgar and Mehta 1988). Scoliosis surgery, successful as regards the Cobb angle, may leave the unsightly rib prominence unchanged or worse, and result in dissatisfaction and disappointment (Clayson and Levine 1976; Edgar and Mehta 1988).

The thoracic asymmetry may be reduced by the excision of segments of the involved ribs (Schollner 1966), and several procedures have been described. Costectomy aims at removal of the entire gibbus (Manning, Prime and Zorab 1973) or of smaller medial sections (Chopin, Briard and Seringe 1980). Such corrections have been maintained by the use of plaster jackets (Laughlin and Mohlenbrock 1980) or the fixation of the residual part of the rib to the remaining medial segment (Owen et al 1986). Some methods use no postoperative immobilisation (Chopin et al 1980) or no rib reattachment (Laughlin and Mohlenbrock 1980). More cosmetic improvement may be gained from reattachment of a resected rib one or two segments caudally; this re-establishes the transverse diameter of the thorax (Schollner 1966). Transfer of the muscle mass from the convex side and augmentation of ribs on the concave side with the resected convex ribs have also been reported to improve the contour of the back (Houghton 1984; Broome et al 1990).

Costoplasty may be performed as a preliminary procedure (Owen et al 1986) or at the time of primary surgery for scoliosis (Steel 1983). Some surgeons reserve costoplasty for use as a secondary operation offered only after skeletal maturity, since they regard immaturity as a contraindication (Manning et al 1973; Broome et al 1990). Good patient satisfaction after costoplasty has been reported (Manning et al 1973; Steel 1983; Owen et al 1986), but no objective measurements have been described and it is difficult to compare the results of different methods, sites of rib resection, and the timing of surgery.

We have made a prospective review of rib prominence after simple short-segment costoplasty without internal or external fixation or muscle transfer. We also compared the results of costoplasty at the time of primary surgery, in patients many of whom were skeletally immature, with those of secondary operations in mature patients.

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PATIENTS AND METHODS

Patients with unsightly rib deformity due to adolescent idiopathic scoliosis were offered costoplasty. Those who were premenarchal or had Risser 0 scores on pelvic radiographs were excluded: they were treated by combined anterior and posterior thoracic spinal fusion. In the first group, 35 patients of average age 14.3 years (12 to 17) had costoplasty during the operation of primary Harrington rod instrumentation and segmental Luque wiring. The second group were 20 mature patients of average age 24.4 years (19 to 35); all had costoplasty as a second procedure after previous Harrington rod fixation and fusion.

Technique of operation. Preoperatively, the extent of the rib prominence is marked on the skin with the patient in a forward-bending position. Through the midline incision used for primary correction of the scoliosis, the lumbar fascia on the affected side is divided longitudinally, and a tissue plane developed between the longissimus and iliocostalis groups of the erector spinae. In the second group of patients who had previously undergone spinal fusion, the approach is through the original midline incision, sometimes with excision of the original scar. Segmental vessels and nerves are preserved, and blunt dissection in the line of the muscle fibres is used to expose the ribs (Fig. 1). Subperiosteal dissection of each rib preserving the neurovascular bundles and the integrity of the underlying pleura then allows a 1.0 to 3.0 cm segment of rib on the medial aspect of the prominence to be removed, using a guillotine osteotome. The heads of the ribs are not removed, but prominent costotransverse joints and transverse processes are trimmed, particularly where the apex of the rib prominence lies medially. The removed rib segments are then used as bone grafts for the spinal fusion. In none of these cases was it necessary to take further graft from the posterior ilium. Before wound closure, saline was poured into the resected rib bed from a 20 ml syringe while the lung was fully inflated and then disconnected from the ventilator for a short period. Either bubbling or the disappearance of fluid during this 'saline test' indicated a pleural puncture which required the insertion of a chest drain. In the absence of a pleural puncture only the rib bed was drained by a small suction drain.

Costoplasty was carried out on an average of five ribs for each patient; it was seldom extended lower than the tenth rib because of the risk of respiratory complications due to the origins of the diaphragm from the eleventh and twelfth ribs.

Postoperative management included an immediate chest radiograph to exclude pneumothorax, chest physiotherapy, and assisted triggered ventilation using a 'Bird' or 'Bennett' apparatus (Bennett Corporation, Palm Springs, CA).

Assessment of results. All patients had preoperative assessment of rib prominence. We used a scoliometer (Bunnell, Orthopaedic Systems Inc, Hayward, CA) to

Fig. 1

Operative removal of a medial rib segment. The segmental vessels can be seen preserved above and below the original rib bed.

Table I. The objective reduction of rib prominence, as assessed by three measurements (mean $\pm$ SD): volume, maximum skin surface angle (MSSA) and Bunnell angulation

	Volume reduction (index)	MSSA (degrees)	Bunnell angle (degrees)
All (n = 55)	6.6 $\pm$ 2.4	7.8 $\pm$ 1.1	11.4 $\pm$ 1.7
Primary costoplasty (n = 35)	7.9 $\pm$ 2.1	9.9 $\pm$ 2.0	11.9 $\pm$ 2.1
Secondary costoplasty (n = 20)	4.1 $\pm$ 1.4	3.5 $\pm$ 0.7	11.0 $\pm$ 1.3

measure the maximal transverse angulation across the midline, and the ISIS (Integrated Shape Imaging System) to record surface topography (Turner-Smith 1982), truncal asymmetry (maximum skin surface angle) and the volume of the costal deformity (volumetric asymmetry and hump severity index) (Fig. 2).

Preoperative and postoperative silhouette radiographs (James 1967) and 30° oblique anteroposterior radiographs were taken. These showed the position and extent of the costoplasty in comparison with preoperative views. Pulmonary function was tested before and after the operation. Patients were followed up at six-weekly intervals until radiographs showed that the ribs had reformed. Final review was at a minimum of two years after operation, and patient satisfaction was recorded on a visual analogue scale.

RESULTS

There was a significant decrease in the volume of the rib prominence, the maximum skin surface angle (MSSA) and the Bunnell angle in both groups of patients (Table I; $p < 0.001$). The reduction of prominence was propor-

ISIS representations of the contour of a patient with scoliosis. Figure 2a – Before primary costoplasty and spinal fusion. Figure 2b – Two years after operation. The volume of the rib prominence is expressed as an index of the volume on the contralateral side and has been reduced from 29.0 to 16.0.

Fig. 2b

Fig. 3a

Fig. 3b

Clinical appearance before (a) and after (b) a secondary costoplasty, showing an average correction.

Fig. 4a

Fig. 4b

Silhouette radiographs of the patient shown in Figure 3 before (a) and after secondary costoplasty (b).

tionally greater in those who had a primary combined procedure ($p < 0.001$). The clinical appearance of an average reduction in a secondary case is shown in Figures 3 and 4. The ISIS scans of patients up to two years after costoplasty showed no statistically significant loss of

correction in either primary or secondary cases. We found no significant difference in this maintenance of correction between the immature (Risser I and II) and the mature (Risser IV to V) patients.

Site of costoplasty. The most effective corrections in

primary costoplasty were obtained by short-segment osteotomies of the most medial part of the ribs (Table II; $p < 0.001$). In the mature rib prominences undergoing secondary costoplasty, however, the greatest correction was produced by excision of a slightly larger segment of rib extending laterally towards the apex of the prominence (Table III; $p < 0.001$; Fig 5).

Rib reformation. All patients showed the reformation of ribs within 3.6 months. In the immature patients the mean time was 3.4 months and in mature patients 3.7 months (no statistical significance). In most patients a 'Z'-shaped regrowth showed that there had been some caudal migration of the lateral cut end. The angular correction of scoliosis was not related to the amount of reduction in rib prominence.

Respiratory function. The results of tests of respiratory function at 18 months were available for 84% of the patients in the study. There were no significant differences between these and preoperative assessments of respiratory function.

Complications. There were eight instances of pneumothorax which did not prolong inpatient stay. Nine patients had an area of altered sensation over the site of their costoplasty, but this did not affect their satisfaction with the result. Three patients were noted to have prominence of the scapula after costoplasty. Where high rib prominences extend under the scapula it may also be distorted; in some cases subperiosteal trimming of the scapula may be indicated, but was not used in our series. The three patients with scapular prominence all had a visible and palpable distal rib which had not been included in the costoplasty; this underlines the importance of marking the extent of rib prominence preoperatively with the patient in a forward-bending position, to ensure that all involved ribs are treated.

DISCUSSION

Our study has shown that costoplasty produces a significant and lasting objective improvement in back shape in both immature and mature patients. Objective corrections were similar or better than those produced by more complex procedures (Broome et al 1990). Although some methods of spinal instrumentation produce partial vertebral derotation, this improvement tends to be transient (Weatherley et al 1987; Edgar et al 1992). We have confirmed that correction by costoplasty does not appear to reduce with time (Bettany, Edgar and Ransford 1992).

The morphology of the abnormal ribs should dictate the preferred sites of osteotomies and allow some prediction of possible correction, but this has not been discussed previously. We have distinguished two types of deformity. Patients with early-onset scoliosis have sharply angulated prominences placed medially, close to the spinous process of the vertebra (type-I rib prominence). Patients with late-onset scoliosis usually have a

Table II. Mean reduction in Bunnell angle of rib prominence related to the site of primary costoplasty. The length of rib removed was similar at each site

Site on rib	Length removed (cm)	Reduction in Bunnell angle (degrees)
Neck	2.7	14 ± 1.3
Tubercle	2.7	11 ± 0.8
Angle	2.4	10 ± 1.0

Table III. Length of rib removed in primary and secondary costoplasties (mean $\pm$ SD)

	Length removed (cm)
All (n = 55)	1.9 ± 0.3
Primary costoplasty (n = 35)	1.6 ± 0.2
Secondary costoplasty (n = 20)	3.0 ± 0.3

Fig. 5a

Fig. 5b

Two types of rib deformity. On the left (a) type I, the curve is medially placed and more acute. On the right (b) type II, the curve is more laterally placed. The most effective sites for resection are indicated above and the postoperative positions are shown below.

more gentle and laterally placed rib curve, with its apex further from the spinous processes (type-II rib prominence; Figs 5 and 6). In general, the earlier the onset of the spinal deformity, the more medial is the apex of the rib prominence. Type-II rib prominences also tend to be longer in the craniocaudal direction. It seems that more mature ribs are less easily distorted.

The shape of the type-I curve suggests that excision of a short segment medially with trimming of the transverse process is the most effective operation. For a type-II curve a longer and more laterally placed rib resection is needed (Fig. 5). Our analysis of the results confirms the importance of using different lengths of resection in type-I and type-II rib prominences. Preoperative marking with the patient in a forward-bending

Fig. 6a

Fig. 6b

Fig. 6c

Silhouette radiographs showing type-I (a) and type-II (b and c) rib deformities.

position is essential to assess the extent of the rib prominence in both medial-lateral and caudal-distal directions. It also allows assessment of the need for subperiosteal scapular trimming.

All our patients were pleased with the procedure, which is easy and simple to perform as an adjunct to primary scoliosis surgery or as a secondary operation. No wiring, postoperative immobilisation or muscle transfer are required and the complications of more extensive surgery are avoided. It is a bonus that the resected rib segments provide good bone graft material and make it unnecessary to take bone from the pelvis in primary fusion cases.

Few patients are unsuitable. Satisfactory lung function is essential; we agree with Broome et al (1990) who suggest that those with FVC (forced vital capacity) of less than 40% of predicted normal should be excluded. In very extreme rotation, the bodies of the vertebrae may

cause the prominence; such cases will not benefit from costoplasty, as is shown on radiographic silhouette views.

The presence of a rib prominence is often the major concern of patients with idiopathic scoliosis, and this is not reliably reduced by current spinal instrumentation. Costoplasty therefore has a definite place in management and although the assessment of any cosmetic procedures is largely subjective, we have provided objective evidence of maintained improvement. Correction is dependent on the type of rib morphology and careful preoperative assessment and planning are required to achieve the greatest cosmetic improvement.

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