GRAND ROUNDS

Bilateral reconstructive costoplasty for razorback deformity correction in adolescent idiopathic scoliosis

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Abstract

Background Correcting the chest wall deformity is an important goal of scoliosis surgery. A prominent rib hump deformity may not be adequately addressed by scoliosis correction alone. It has been shown that costoplasty in conjugation with scoliosis correction and instrumented spinal fusion is superior to spinal fusion alone in addressing the chest wall deformity. In cases of severe rib hump deformity unilateral convex side costoplasty alone might not adequately restore thoracic cage symmetry necessitating for additional concave side rib cage reconstruction.

Case report A 16-year-old male with adolescent idiopathic scoliosis and a sharp, cosmetically unacceptable, prominent rib hump (razorback deformity) underwent scoliosis correction with posterior spinal fusion and bilateral costoplasty. The convex-sided ribs were resected and used for concave-sided rib reconstruction. The rib hump height was reduced from 70 mm before the procedure to 10 mm after the procedure and the apical trunk rotation was reduced from 36° to 5°, respectively. Solid spinal fusion and ribs union was achieved. The patient remained very satisfied with no loss of correction at 2-year postoperative follow-up.

Conclusion Bilateral costoplasty in conjugation with scoliosis correction may provide a safe and effective method for the treatment of severe rib cage deformities associated with thoracic scoliosis. It should be considered in the presence of prominent rib hump deformity, where scoliosis correction alone or with unilateral costoplasty is unlikely to provide adequate correction.

**Keywords** Razorback deformity · Rib hump · Scoliosis · Thoracoplasty · Costoplasty · Plate · Screw

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Case presentation

A 16-year-old male was followed-up by our spine team due to progression of his adolescent idiopathic scoliosis (AIS). The patient complained on cosmetically unappealing, progressive, right-sided rib hump deformity affecting his social life and moderate back pain at apex of deformity in activities of daily leaving. He had no
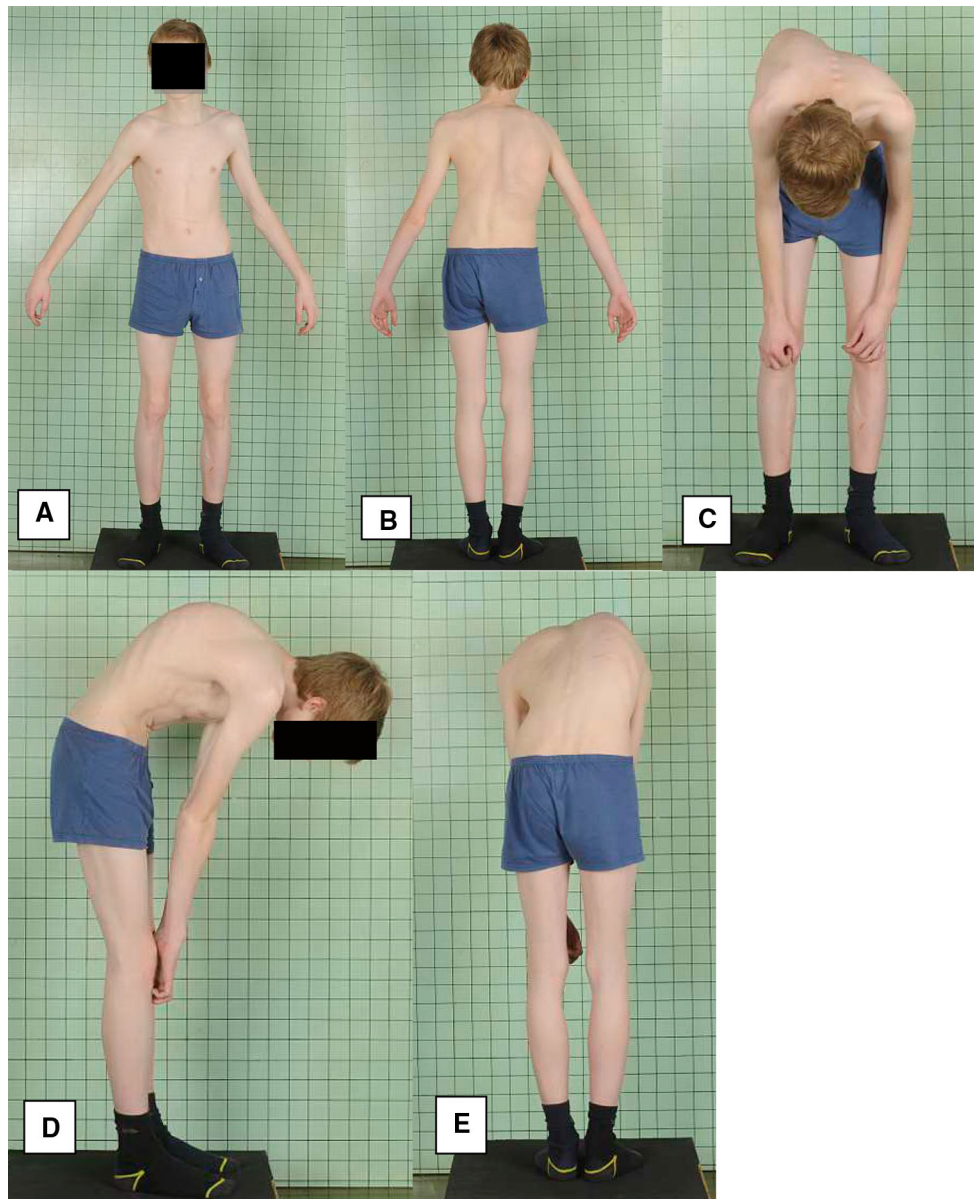
Fig. 1 Pre-operative images showing the severe rib hump deformity "Razor Back". **a** Standing straight anterior view, **b** standing straight posterior view, **c** anterior bending—anterior view, **d** anterior bending—lateral view, **e** anterior bending—posterior view

other comorbidities and otherwise unremarkable medical history. Non-operative treatment with physiotherapy and analgesics over a 12-month period failed to improve his symptoms. Physical examination revealed no neurological abnormalities. There were no signs of cord compression, nerve root irritation or pathological reflexes. Forward bending test revealed a sharp right-sided razorback deformity with rib hump measuring 36°, 70-mm high, without compensatory left-sided loin hump. The left shoulder was measured 20-mm higher than the right one. The pelvis was balanced with neutral sagittal axis and mild right truncal shift (Fig. 1).

Diagnostic imaging section

Whole spine unsupported standing X-rays showed a right thoracic Lenke 1AN scoliosis with the apex located at T8. Over a 2-year follow-up, the curve progressed from 36° (T6–T12) to 64° and compensatory left lumbar curve was developed. On forced side bending films the thoracic curve decreased to 46 degrees and the lumbar curve straightened out to zero (Fig. 2). Whole spine MRI showed mild hydromyelia in the thoracic spine (an incidental finding) with no neural axis pathologies (e.g. Chiari malformation, tethered cord, cysts or cord compression).
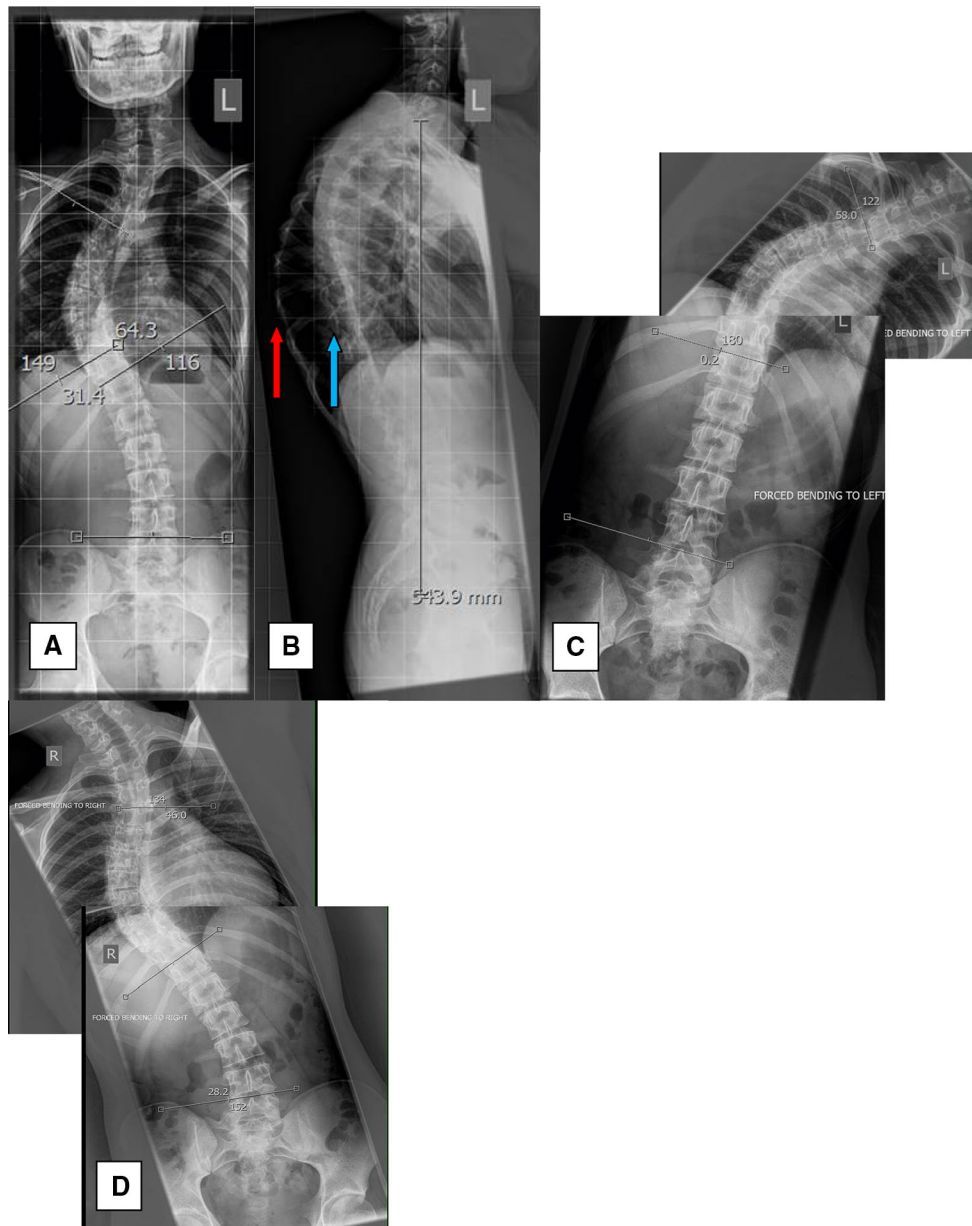
Fig. 2 Pre-operative X-rays. **a** Anterior posterior image, 64° right thoracic curve, **b** lateral image, neutral sagittal balance, large rib cage asymmetry—*red arrow* convex side ribs, *blue arrow* concave side ribs **c** forced bending to the left, straightening of lumbar curve, **d** forced bending to the right with thoracic curve reduction to 46°

Historical review, epidemiology, diagnosis

In idiopathic scoliosis the most important components of the deformity are the thoracic rib hump, the lateral shift of the chest relative to the pelvis and the asymmetry of the shoulders [1, 2]. The last two are easily recorded photographically and radiographically and on the whole are correctable by either bracing or operation [1]. The rib hump is the feature of the deformity most resented by the patient, least understood by the surgeon and most resistant to treatment [3]. Lonstein et al. [4] screened 80,144 children and found that 9.1 % had rib humps. Most frequently patients present with a right thoracic curve and right-sided rib hump. As scoliosis deformity develops around all three orthogonal axes, the rib cage adapts to these abnormal stresses imposed by the spine curvature and develops altered shape; this is clinically apparent as rib hump on the curve convexity and can be best seen on forward bending test [5]. The ribs on the convexity are rotated backward and acquire an increased angulation at the level of the posterior angle. Thoracic coronal plane diameter is reduced, reducing the overall chest volume on

this side with reciprocal changes occurring on the concavity [6, 7]. The exact etiology of the rib hump remains unclear, there is no direct relationship between the rib hump size and the degree of neither lateral curvature nor the amount of vertebral rotation [2, 8], therefore, cosmetically disturbing rib prominence can exist without significant coronal plane deformity or even after complete surgical correction of the scoliotic curve. In recent years, direct vertebral derotation (DVD) [9] and vertebral coplanar alignment (VCA) [10] techniques have been introduced in aiming to reduce the rotation of the apical vertebrae and to correct the rib hump deformity without the need for costoplasty. The effectiveness of these techniques to achieve vertebral derotation is still controversial with evidence supporting [11, 12] and apposing its efficacy [13, 14]. Several studies found no advantages of DVD/VCA techniques over conventional road derotation methods in correcting the thoracic rib hump associated with scoliosis [12, 13]. Whilst the correction of scoliosis does have a beneficial effect on the posterior chest wall symmetry, the more sharp angular rib deformity in razorback is far more likely to persist after isolated-surgical correction of the scoliotic curve. Clear evidence from prospective trials on this specific constellation is, however, lacking due to the uncommon presentation hereof and clinicians are required to find the best possible surgical solution to optimize reconstruction of chest wall symmetry. Thus, it seems that uni/bilateral costoplasty should still be considered as the favorable technique to correct large rib humps [15–24].

Rationale for treatment and evidence-based literature

The most common indication for costoplasty is patient dissatisfaction from their appearance. The unilateral rib prominence often seen in AIS is frequently patients' main concern, and may cause social and psychological damage [6, 25, 26]. There is no objective measure for costal deformity size needed to produce a subjective cosmetic problem. The aims of operation are to prevent scoliosis progression and to improve appearance, but posterior instrumentation alone does not completely correct rib rotation [27] and may leave the unsightly rib prominence unchanged resulting in dissatisfaction and disappointment to our patients [28].

The indication of surgical intervention in our patient was his unwillingness to accept his large rib hump deformity. On forward bending test thoracic rib hump can be classified as (1) mild ≤9° (2) moderate 10–15° (3) severe ≥16° [29]. Most studies suggest that rib hump prominence >15° or 3 cm on forward bending test should be considered as a relative indication for costoplasty in addition to scoliosis correction [21, 29]; whereas, larger chest wall deformities may require bilateral costoplasty for adequate correction [29].

There are two main types of rib deformities. Patients with early onset scoliosis have sharply angulated prominences placed medially, close to the spinous process of the vertebra (type-I rib prominence); whereas patients with late-onset scoliosis usually have a more gentle and laterally placed rib curve, with its apex further from the spinous processes (type-II rib prominence) [20].

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 [20].

Despite the significance of the rib hump in scoliosis correction only few studies compared the outcome of different surgical methods for ribs hump correction (e.g. unilateral versus bilateral costoplasty, amount of rib resection needed, type and method of rib fixation, etc.) [15–24].

Several procedures have been described for correction of rib hump in AIS. Dorsal convex side costoplasty (simple costectomy) is the most common technique described; the technique was performed initially in 1973 by Manning et al. [16] as a late second-stage procedure after scoliosis repair with remaining thoracic rib hump. Only 10 years later, Steel et al. [18] incorporated costoplasty as an integral part of the primary scoliosis repair. Mild thoracic asymmetry may be corrected by costectomy of the ribs alone, whereas moderate deformities may necessitate excision of bone segments from the involved ribs on the convex side [15]. As the ribs on the convex side are caudally oriented, Schollner costoplasty [19] further improves cosmetic appearance by reattachment of a convex resected rib one or two segments caudally, re-establishing the transverse diameter of the thorax [19, 24]. For severe deformities, Briard et al. [15] reported on a technique using the resected convex ribs as bone graft for reconstruction of the concave rib cage shape, this further improves the contour and symmetry of the back, in his cases resected ribs were attached by metallic staples [19, 24]. Our patient presented with severe type II thoracic deformity (36°, 70 mm high). We used the Schollner and Briard methods to achieve optimal correction. The literature supporting our choice of combined procedure is scarce; Broome et al. reported on 2 cases of combined procedure (one congenital scoliosis the other using Harrington rods) [19], Harding et al. [24] reported on 7 cases (using Harrington rods); interestingly enough in their study no cosmetic change was noticed between the unilateral and bilateral costoplasty. We learned from their experience and to achieve stronger bone graft fixation and better reconstruction of the concave side we used 1/3 tubular plates fixated with screws in
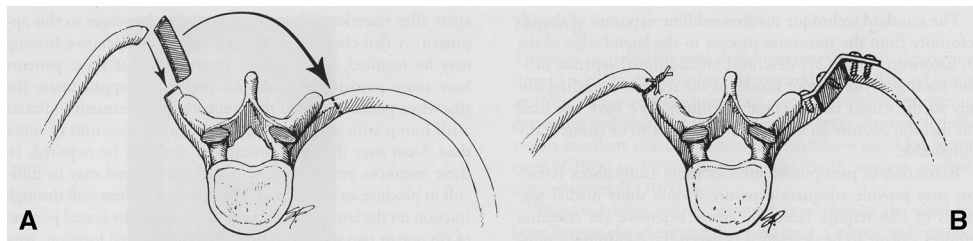
Fig. 3 Costoplasty illustration, **a** cutting a rib segment from the convex side, cutting the rib on concave side. **b** End-to-end rib attachment on convex side (in our case done with 1/3 tubular plate for stronger fixation), rib segment attached to concave side— reconstructing the ribcage shape by molding the 1/3 tubular plate into "Z-shape" (illustration contributed with permission from "Pediatric Spine Surgery" a book by S. Weinstein)
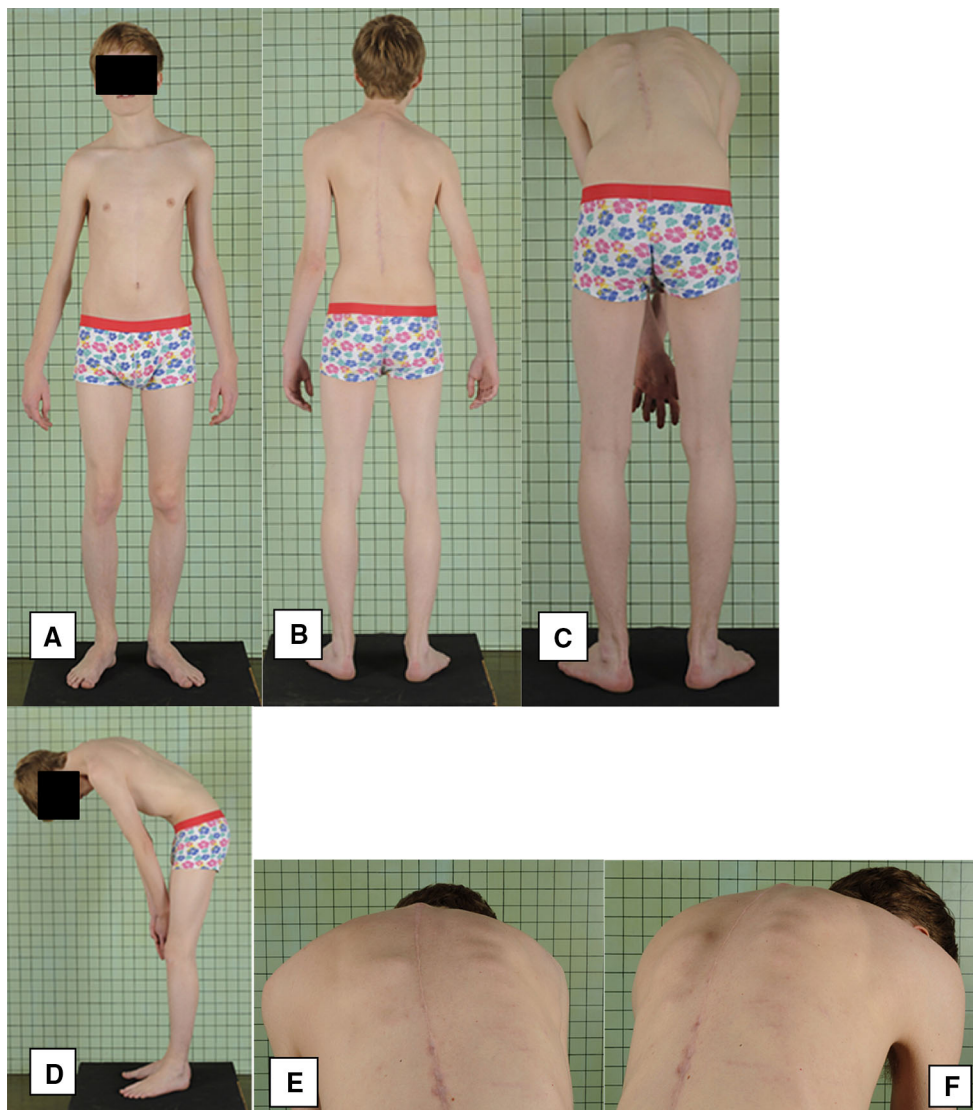
Fig. 4 One-year postoperative images showing the rib hump correction. **a** Standing straight anterior view, **b** standing straight posterior view, **c** anterior bending—posterior view, **d** anterior bending—lateral view, **e**, **f** anterior bending—posterior view

contrast to their method of graft fixation with wire and metallic staples. The length of rib to be resected is effected by the flexibility of the deformity; In rigid type II deformities removal of the entire gibbus may be required [16], while only part of it may be required in flexible type I ones [15]. Deformity corrections can be maintained post-

Fig. 5 Whole spine postoperative standing X-ray images showing the reconstruction of deformity with thoracoplasty of T6–T10 ribs, **a** anterior–posterior image on convex side (*right*) end-to-end attachment of the ribs using straight 1/3 tubular plate, on concave side (*left*) end-to-end attachment of the ribs using "Z-shape" 1/3 tubular plate achieving symmetry to rib cage **b** lateral image, showing symmetry in rib cage reconstruction

costoplasty using plaster jackets [17] or by end-to-end fixation of the residual part of the rib to the remaining medial segment using wires or plates [30]. Some methods use no postoperative immobilization and no rib reattachment [17].

Costoplasty should be avoided in very young skeletally immature patients and with patients with poor pulmonary function (if lung function test shows 30 % decreased values compare to predicted ones, patient will have difficult postoperative course). Steel et al. [18] found 12 % decline in pulmonary function test 2 weeks after surgery, but 90 % of patients reached or exceeded their preoperative lung function test by 1 year time, similar results were described by Chen et al. [31].

Geissele et al. [29] found that in 93 % of patients after convex side costoplasty alone reported cosmetic improvement in their rib hump and that 86 % were willing to go through with the procedure again. However, their encouraging results were performed on rib prominence of 4.5 ± 1.3 cm where in our case a rib prominence of 7 cm

was noticed. Steel et al. [18] had only 3 % cases with unsatisfactory results, half of which are due to inadequate rib resection. Rib fusion was found in all patients 3.4 months after surgery [20]. There was no significant difference in the 2 years results in immature patients (Risser 1–2) compared with the more skeletally mature patients [20, 32].

Pre surgical assessment and surgical technique

Preoperatively we assessed the deformity using antero-posterior and lateral unsupported standing radiographs of the whole spine including the pelvis and femoral heads. The scoliosis curve magnitude, sagittal balance, truncal shift and shoulder height were evaluated. Side bending radiographs were performed to assess of curve flexibility. Whole spine MRI was performed in query of associated spine pathologies which may affect the surgical procedure (e.g. cord tethering, Chiari malformation, syrinx, etc.). Such pathologies were reported in 10 % of idiopathic scoliosis cases [33].

The procedure was performed in the prone position under general anesthesia and continuous neuro-monitoring. The borders of the deformity were marked preoperatively in standing forward bending position (since in the prone position on the operating table the rib hump usually flattens resulting in underestimation of its magnitude). The medial and lateral rib hump borders dictate the amount of required rib resection. The amount of rib resection varies in different reports, some studies reported on 2-cm convex-side rib resection [20] while other resected up to 12 cm of rib length [18]. Best rib hump correction was achieved in patients undergoing a rib resection 3 cm beyond the apex of deformity [20].

We used a bilateral costoplasty technique performed through the midline incision used for the primary correction of the scoliosis deformity. The lumbar fascia divided longitudinally and a plane was developed over the longissimus and ilio-costalis groups of the erector spinae muscle, which were then medially retracted to expose the lateral edge of the deformity. To avoid extensive muscle dissection the plane can be developed by blunt finger dissection over the respective rib. We used electro-cautery to cut the periosteum over the rib and periosteal elevators to strip it, remaining in close vicinity to the sub-periosteal plane to avoid damaging the neurovascular bundle along the inferior ribs border and to reduce the risk of breaching the parietal pleura (this plane can be developed until the posterior axillary line). We used power saw to remove a segment of approximately 5–7 cm of the 6th–10th ribs on the convex side. The resected segments were used later on as structural bone
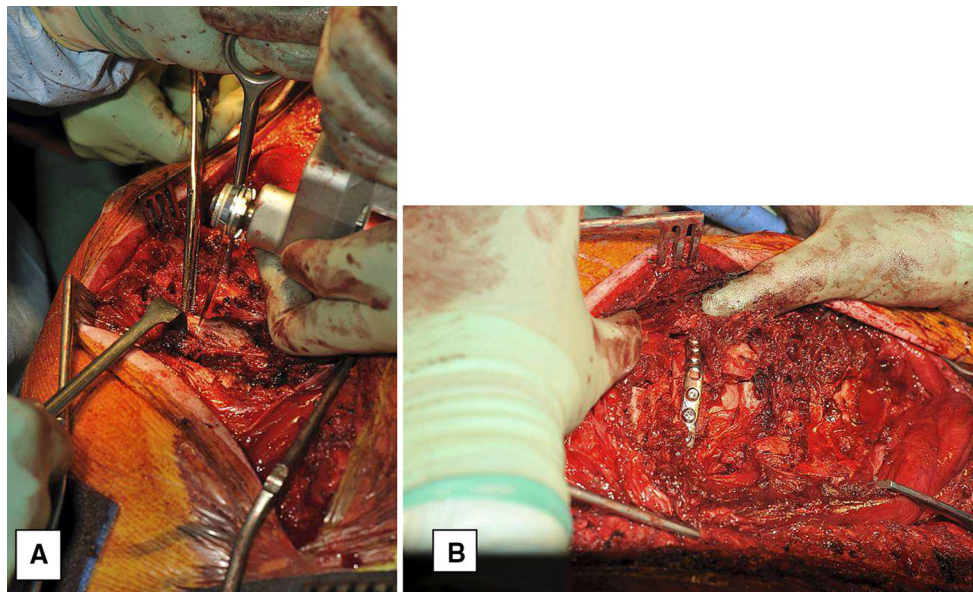
Fig. 6 Intra-operative images, **a** cutting of the rib with powered bone saw, **b** fixation of rib with 1/3 tubular straight plate and 3.5 mm cortical screws on the convex side

graft for the concave side reconstruction. Each rib at the convex side was fixed to the costo-transverse rib stamp at the adjacent inferior level with 1/3 tubular plates (contoured in a wide angle shape) and 3.5-mm cortical screws (to enable rigid fixation which would allow early mobilization). At the concave side we osteotomised the involved ribs (7th–10th ribs) 1 cm lateral to the transverse process and used contoured "Z-shaped" 1/3 tubular plates (4 or 5 holes plates were used) to raise the level of the ribs to match the convex side. If the transverse processes are prominent and contributing to deformity they should be resected (this was not the case in this procedure). We prefer to approximate the ribs when possible [16]; to achieve stronger rib graft fixation (especially on the concave side) and better thoracic cage reconstruction the use of AO/ASIF 1/3 semi-tubular plate with 3.5 cortical screws for fixation is our preferred option (Fig. 3). If the rib resection is more than 3 cm wide re-approximation at the same level may be difficult (or cause unacceptable skin dimple), therefore, necessitating moving the rib one or two levels inferiorly. Moving of ribs inferiorly further flattens the hump [15, 19].

To detect pleural injury we immersed covered the surgical field with saline solution searching for air bubbles (no air leak was noticed). As haemothorax, pneumothorax and pleural effusions are common complications (even without pleural breach) insertion of prophylactic chest drain is done routinely by us. Chest wall hypoesthesia or neuralgia may be present in 15–24 % of patients [20, 29], therefore, a strict sub-periosteal exposure of ribs and avoidance of

incorporation of the neurovascular bundle in suture line if closing the periosteum is important.

Penicillin-based antibiotics were given prophylactically for 24 h postoperatively. In mature adolescent we administer routinely chemical and mechanical thrombo-prophylactics.

Outcome

The operation time was 5 h (scoliosis correction with posterior spinal fusion and bilateral costoplasty) and the blood loss was 900 ml. No loss of monitoring was observed during curve reduction. At postoperative day 1 the patient remained in bed in a reclining position with continuous analgesia. At postoperative day 2 he was allowed to sit on a chair, chest drain removed (draining of less than 50 ml in 12 h). Assisted walking was initiated on postoperative day 3. The patient was discharged from our department at postoperative day 6. Postoperatively the rib hump height decreased from 70 mm before the procedure to 10 mm after the procedure and apical trunk rotation was reduced from 36° to 5°, respectively. Uneventful healing was documented after discharge at 1.5, 3, 6, 12 and 24-month follow-up. No hardware loosening was observed.

At 6 months the patient was allowed to return to non-contact sport and at 12 months to unrestricted sport activities. At the latest follow-up of 24 months the patient remained very satisfied with his appearance with no loss of correction (Figs. 4, 5, 6).

Conclusions

Bilateral costoplasty in conjugation with scoliosis correction may provide a safe and effective method for the treatment of severe rib cage deformities associated with thoracic scoliosis. It should be considered in the presence of prominent rib hump deformity, where scoliosis correction alone or with unilateral costoplasty is unlikely to provide adequate correction.

Conflict of interest   None.

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