Crossing osteotomies and rib transposition for coverage of a moderate-size bony thoracic defect

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5 THERAPEUTIC

Full-thickness defects of the chest wall are managed based on the principle of restoring structure and function. Characteristics of the lesion, such as size, location and etiology, as well as its resultant effects on pulmonary mechanics govern the surgical approach to reconstruction. Defects of intermediate size, however, occupy a gray area in thoracic wall reconstruction, with no clear consensus on management. The authors describe a novel method of providing bony coverage for a moderate-size thoracic wall defect in a patient with a complex intrathoracic, extrapleural hernia by crossing osteotomies in addition to transposition and fixation of ribs. Osseous rib Z-plasty is a novel surgical technique that may be considered to be a valid alternative for reconstruction of selected moderate-size, full-thickness defects of the lateral rib cage. Knowledge of this technique is recommended for thoracic, trauma and plastic surgeons who are likely to encounter and manage such defects.

Key Words: *Autologous bony transposition; Chest wall reconstruction; Osseous Z-plasty; Thoracic defect*

Full-thickness defects of the chest wall are managed based on the principle of restoring structure and function. Characteristics of the lesion, such as size, location and etiology, as well as its resultant effects on pulmonary mechanics, govern the surgical approach to reconstruction.

Small bony thoracic wall lesions <5 cm at any location on the thoracic wall may be managed with soft tissue coverage alone without notable impact on pulmonary function (1). Additionally, posterior lesions up to 10 cm in diameter are afforded adequate protection by the scapula, provided the lesion does not involve the region of the scapular tip, which may impinge on the defect. Large bony defects not protected by the scapula render the thoracic viscera susceptible to traumatic injury and are significantly more likely to cause paradoxical motion during respiration and, potentially, pulmonary insufficiency. Defects of intermediate size, however, occupy a gray area in thoracic wall reconstruction, with no clear consensus on management.

We describe a novel method of providing bony coverage for a moderate-size thoracic wall defect in a patient with a complex intrathoracic, extrapleural hernia by crossing osteotomies in addition to transposition and fixation of ribs.

CASE PRESENTATION

A 69-year-old obese man with an extensive history of multiple ventral hernias presented for evaluation of a complex incisional hernia following thoracotomy and open repair of a thoracoabdominal aortic aneurysm. Approximately two months following repair of his aortic aneurysm, the patient noted a progressively enlarging bulge in his left upper quadrant and flank. The patient reported discomfort without pain, change in appetite or bowel habits. On examination, a pronounced left upper quadrant hernia was easily reducible and demonstrated no signs of incarceration or strangulation (Figure 1). Computed tomography imaging revealed herniation of the bowel, originating in an incisional defect in the abdomen, which progressed in a cephalad direction to the thorax (Figure 2). The bowel then transited into the thoracic cavity through a soft tissue defect between widely displaced sixth and seventh ribs. This bony defect was suspected to be secondary to the previous thoracotomy and rib spreading. The complex hernia extended for the full anterior to posterior length of these ribs and was noted to have a maximum superior to inferior intercostal distance of approximately 10 cm anterolaterally.

Figure 1) *Preoperative evaluation demonstrating left upper quadrant hernia*

The patient was brought to the operating room for repair of the complex incisional hernia, which involved a multiteam approach by the thoracic, plastic and general surgery services. On exploration of the thoracic extent of the hernia tract, the defect was encountered, serving as the suspected entry point for the bowel. Although no bowel was present in the thorax at the time of surgery, hernia sac was found in an intrathoracic, extrapleural location. After limited pneumolysis, the hemidiaphragm was visualized and explored for a possible defect permitting intrathoracic herniation of abdominal contents, but was found to be in continuity. The hernia sac was deemed to course subcutaneously over

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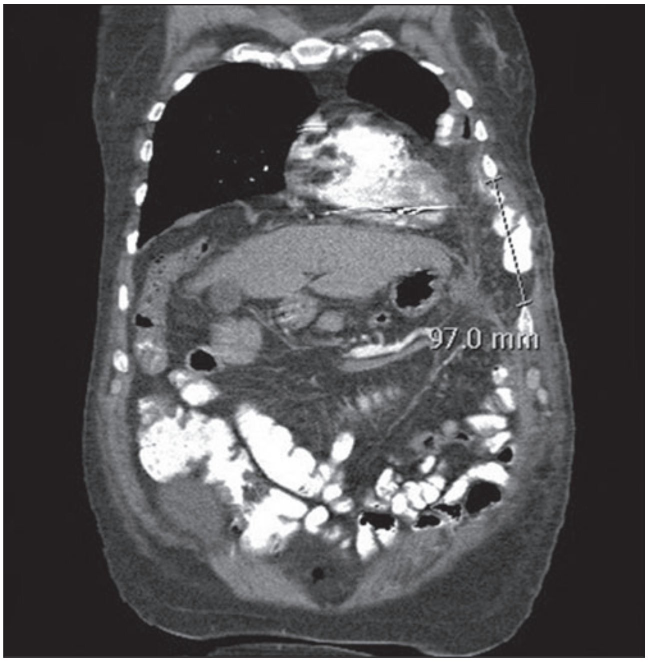

Figure 2) *Computed tomography image demonstrating a costal defect of 9.7 cm and the presence of bowel intrathoracically*

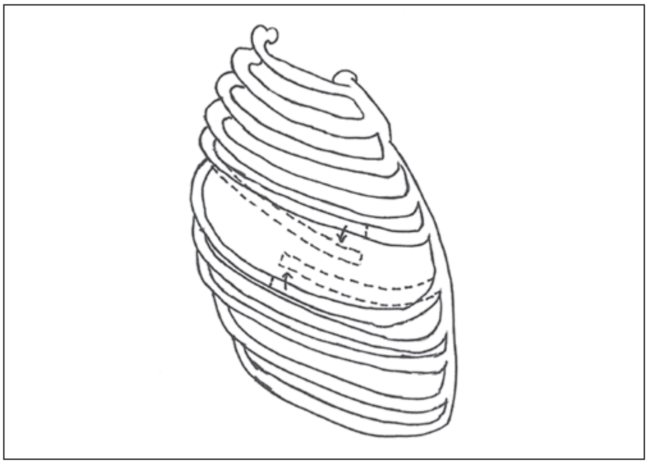

Figure 3) *Schematic representation of osseous rib Z-plasty as described above*

the costal margin and intrathoracically through the costal defect, confirming the computed tomography findings.

The substantial distance between adjacent ribs would not allow the defect to be reliably reapproximated primarily without undue tension. Further, due to this patient's medical comorbidities and associated risk for infection, we were reluctant to use classic thoracic reconstruction techniques employing the use of prosthetic mesh. We, therefore, elected to repair the lesion with a novel surgical approach using autologous thoracic wall reconstruction via an osseous rib Z-plasty (Figure 3). This technique allowed for both a minimal tension approximation of bony tissue as well as obliteration of the pleural dead space due to the inward displacement of the mobilized ribs. The sixth and seventh ribs ribs were identified and their associated intercostal muscle and vascular bundles were isolated inferiorly, ligated and divided. Osteotomies were performed anteriorly on the sixth rib and posteriorly on the seventh (Figure 4). These ribs were then mobilized and brought into apposition with one another in Z-plasty fashion using 1-0 Ethibond sutures (Figure 5). Subsequently, the fifth and eight ribs were sutured to the corresponding sixth and seventh ribs, respectively, forming an oblique

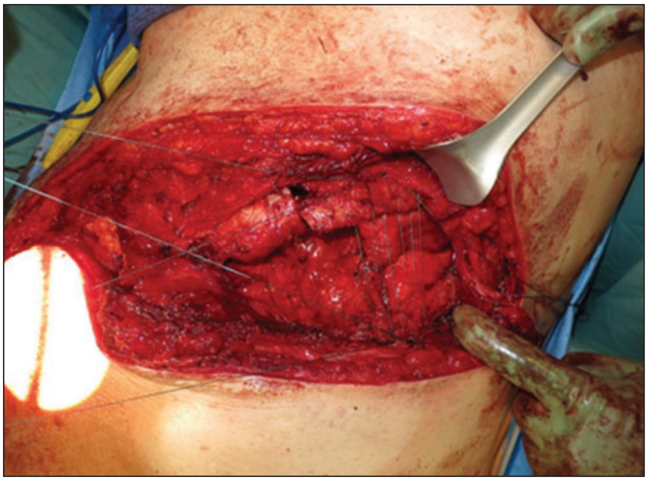

Figure 4) *Rib Z-plasty before approximation*

couplet. The divided serratus anterior was then mobilized both inferiorly and superiorly and the muscle was imbricated with 0 Vicryl sutures to provide soft tissue coverage of the hernia defect.

The thoracic team proceeded to repair an existing costosternal defect and the remainder of the abdominal extent of the hernia was repaired laparoscopically by the general surgery team. The patient's postoperative hospital course was uncomplicated and he was discharged home on postoperative day 4.

One week after discharge, the patient was evaluated at an outside hospital for complaints of right-sided (contralateral) flank and back pain. Thorough evaluation and imaging failed to reveal a cause of the patient's pain, which subsequently resolved. Computed tomography did not reveal any pathology related to the patient's recent hernia repair. The patient was subsequently evaluated by the surgical teams three weeks postoperatively, at which time he reported no complications related to his surgery. He denied pain and discomfort, and exhibited no pulmonary dysfunction. Examination revealed a well-healed incision, significant reduction in the size of the left upper quadrant bulge, and no evidence of hernia or donor site morbidity (Figure 6). The patient continues to be followed for routine surveillance.

DISCUSSION

Chest wall reconstruction is most frequently indicated due to tumour resection, radiation necrosis, infection and trauma (2). The operative goals of reconstruction in patients with full-thickness defects of the thoracic wall are to maintain an airtight pleural cavity, to re-establish chest wall integrity to protect the thorax contents from infection and trauma, to preserve or re-establish pulmonary function, and to provide an acceptable cosmetic result (3,4). Reconstructive options are varied and largely dependent on the size and location of the defect, as well as the effect of the lesion on pulmonary mechanics.

Small, full-thickness thoracic wall defects exhibit little risk for negatively impacting pulmonary function and are almost exclusively managed operatively by local soft tissue coverage with muscle or myocutaneous flaps. Hanna et al (5) demonstrated that osseous defects of up to 60 cm^2 could be repaired with pedicled myocutaneous flaps alone without impairing pulmonary function. Large bony defects, however, are significantly more likely to adversely affect pulmonary mechanics and leave the underlying thoracic viscera unprotected from blunt traumatic injury. More extensive reconstructive techniques are, therefore, used to recreate the original architecture of the chest wall in such lesions. When sutured under tension, synthetic mesh can offer semirigid fixation and good skeletal support, although this effect is material dependent (6). Alternatively, rigid fixation using methylmethacrylate in conjunction with synthetic mesh, as well as rib osteosynthesis systems, may be used; however, the

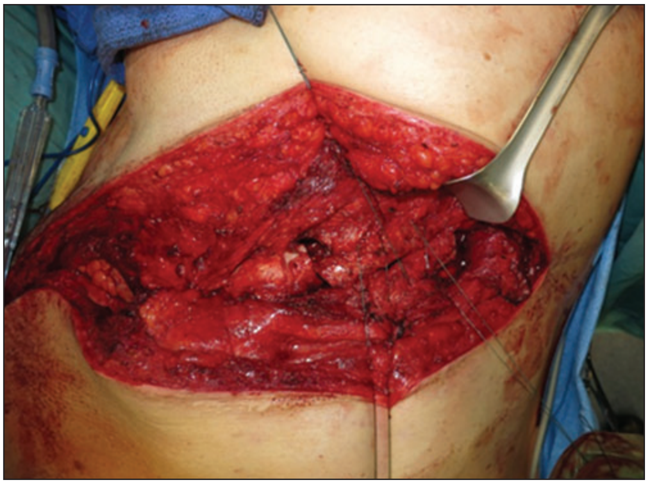

Figure 5) *Rib Z-plasty after approximation*

Figure 6) *25-day post-operative image demonstrating no evidence of hernia*

precise role of rigid reconstruction with regard to pulmonary mechanics remains controversial (7).

In the present case, we encountered the unique problem of a sizeable intercostal defect of the lateral thoracic wall secondary to bony displacement and markedly increased intercostal distance rather than true loss of bony tissue. This full-thickness defect was initially closed with soft tissue alone. Subsequent breakdown of this previous repair permitted the migration of bowel into the thoracic cavity; therefore, we believed that rigid coverage of the defect was necessary to adequately prevent hernia recurrence. Primary repair of the displaced ribs was not possible due to defect size and post-thoracotomy rigidity. Similarly, utilization of a synthetic patch to bridge the defect at the level of the rib would have left a substantial well-formed space deep to that patch due to the intrathoracic migration of hernia sac, promoting pleural effusion and/or empyema. Furthermore, the risk of infection with mesh use was high based on the patient's comorbid conditions. Intrathoracic transposition of autologous muscle flaps, including the latissimus dorsi, serratus anterior, rectus abdominis, serratus anterior, rhomboid and intercostal muscles, has been reported for use in obliterating thoracic dead space (3). The combination of using an autologous tissue flap for dead space obliteration as well as a synthetic mesh bridge to provide rigid support was considered; however, rigid coverage was deemed necessary to prevent hernia recurrence. Osseous modification of the Z-plasty technique allowed for significant mobilization of the ribs, which permitted rigid coverage of the defect and offered several advantages over conventional reconstruction methods. Traditionally, the benefits of true Z-plasty lie in lengthening and the re-orientation of scar contracture forces. Additionally, in true Z transposition, one flap always reconstructs the donor site of the other flap, which is one of the greatest benefits of the Z design and triangular flap interposition or transposition. Of note, in this technique, the secondary defect is left open.

Reconstruction of chest wall defects using autologous rib have been thoroughly described, especially in the pediatric surgical literature in patients with Poland syndrome. Split rib grafts have been successfully used to fuse hypoplastic ribs with or without the need for supportive struts (8) for two-stage chest wall reconstruction in Poland syndrome patients. Zhou et al (9) described rib transposition in a pediatric patient with Poland syndrome. In that case, absent anterior portion of the fifth rib, and fused seventh and eighth ribs resulted in a 123 cm × 148 cm defect, comparable in size and character with the rib cage defect we observed in the present case. The authors elected to disarticulate and remove rib V, and then transposed the sixth rib into the chest wall defect, securing the transposed rib to the sternum with K-wire.

The osseous rib Z-plasty, in combination with soft tissue coverage, created a physical barrier preventing recurrent intrathoracic transit of bowel. This technique also protected the thoracic viscera from traumatic injury by providing rigid coverage of the bony deficit. The use of autologous tissue provided viable, vascularized rigid coverage of the defect, providing more resistance to and better eradication of infection than available synthetic mesh options. Autologous tissue is rarely used for rigid reconstruction of the chest wall due to significant donor site morbidity and the availability of excellent prosthetic alternatives. However, synthetic mesh and osteosynthesis sytstems put the patient at risk for foreign body infection. Such infections typically necessitate excision of the foreign body, which would have subjected this high-risk patient to an additional procedure (1,10-12). Furthermore, in this unique circumstance, the collapsing displacement of the osteotomized and apposed ribs reduced intrathoracic dead space occupied by the hernia, mitigating persistent effusion and/or empyema.

We envision that this technique may also be applicable in the management of symptomatic moderate-sized bony thoracic wall defects resulting from the resection of up to two ribs (Figure 7). As noted, the maximum preoperative intercostal distance between the patient's left sixth and seventh ribs was nearly 10 cm, yet through the use of the osseous Z-plasty technique we were able to bring those ribs into direct apposition. Radiological measurements of the patient's unaffected contralateral thoracic wall revealed lateral intercostal distances of approximately 2.8 cm between adjacent ribs and 5.8 cm between ribs separated by an intervening rib (ie, fifth and seventh ribs). Osteotomies of the intact ribs superior and/or inferior to the defect, as described above, allowed their mobilization and enabled collinear, rigid fixation to the adjacent resected ribs, achieving osteosynthesis. Defects of up to two resected ribs may conceivably be covered using this technique with minimal tension, minimal anticipated effect on pulmonary mechanics and limited donor site morbidity. To accommodate increased intercostal defect height and/or anterior-posterior defect length, the distance between osteotomies must also necessarily increase.

Alternative methods of fixation are an area of potential modification to this technique. In the present case, nonabsorbable sutures were placed circumferentially around the two ribs and secured to bring them into apposition. However, more stable fixation methods are available. We envision potential osteosynthesis through the use of fixation plates and screws to provide permanent, rigid fixation of the apposed ribs.

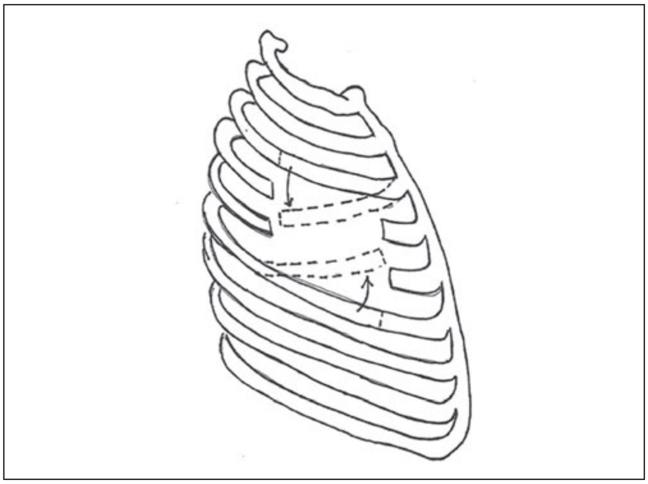

Figure 7) *Schematic representation of proposed use of osseous rib Z-plasty for bony coverage of a two-rib defect*

Similarly, the use of permanent sutures or K-wires threaded through drilled osteotomies may provide a more stable, long-term fixation.

Anatomical location of the lesion limits the technical feasibility and overall applicability of osseous rib Z-plasty to defects of the lateral thoracic wall between the anterior and posterior axillary lines. The presence of the costal cartilage and sternum precludes its use in the management of anterior defects. Furthermore, such lesions are commonly and successfully managed via soft tissue coverage alone, by means of pectoralis major advancement/turnover or omental flaps (13). Posteriorly, the scapula functions to provide structure to the chest wall and protection of the underlying organs, while also preventing paradoxical chest wall motion and lung herniation.

Additionally, this technique is likely suited to moderate-size thoracic wall defect only; both large and small full-thickness thoracic defects are unlikely to be amenable to osseous rib Z-plasty. Repair of large lesions would necessitate substantial mobilization of the osteotomized ribs, creating undue tension across the repair. In addition to the considerable pain and discomfort this would likely cause the patient, such tension may, in fact, restrict chest wall dynamics during respiration. Affixation of the ribs may further limit excursion of the thoracic cage, and could lead to pulmonary embarrassment. As with any tissue transfer, donor site morbidity must also be considered. Large primary defects expectedly result in large secondary defects, promoting lung herniation at these locations. Similarly, small defects also do not lend themselves well to osseous Z-plasty. Acute angulation of the osteotomized rib would be necessary to bridge the lesion, likely requiring additional wedge osteotomies to sufficiently hinge the rib, which would risk vascular compromise of the mobilized rib. Such a risk is difficult to justify given the availability of successful and less morbid management options.

Careful patient selection is critical in determining appropriate candidates for this reconstructive method. Patients with pre-existing pulmonary disease may be poor candidates for osseous Z-plasty because this technique has the potential to impair pulmonary mechanics. Furthermore, care must be taken in applying this technique to patients who have previously received irradiation; existing vascular compromise secondary to fibrosis may jeopardize the viability of the osteotomized ribs (3). In addition to prognosis, donor site morbidity and aesthetic considerations, the surgeon must also appreciate patient lifestyle and/or occupation in planning thoracic wall reconstruction with osseous Z-plasty. This procedure may not be practical for young, healthy patients, or patients whose occupation requires a high degree of physical activity. Such individuals may realize a greater benefit from reconstruction with mesh or methylmethacrylate and soft-tissue coverage, which may allow for better preservation of dynamic chest wall function.

In conclusion, osseous rib Z-plasty is a novel surgical technique that may be considered as a valid alternative for reconstruction of select moderate-size, full-thickness defects of the lateral rib cage. We have demonstrated its utility in restoring chest wall integrity in a patient with a unique thoracic pathology. Knowledge of this technique is recommended for thoracic, trauma, and plastic surgeons likely to encounter and manage such defects at the time of surgery. Although osseous rib Z-plasty is unlikely to replace established primary operative methods of chest wall or rib cage reconstruction, it may prove valuable in expanding the surgeon's armamentarium of rigid thoracic reconstructive techniques.

DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES

1. Deschamps C, Tirnaksiz BM, Darbandi R, et al. Early and long-term results of prosthetic chest wall reconstruction. J Thorac Cardiovasc Surg 1999;117:588-91.
2. Arnold PG, Pairolero PC. Chest-wall reconstruction: An account of 500 consecutive patients. Plast Reconstr Surg 1996;98:804-10.
3. Ferraro P, Cugno S, Liberman M, Danino MA, Harris PG. Principles of chest wall resection and reconstruction. Thorac Surg Clin 2010;20:465-73.
4. Holton LH, Chung T, Silverman RP, et al. Comparison of acellular dermal matrix and synthetic mesh for lateral chest wall reconstruction in a rabbit model. Plast Reconstr Surg 2007;119:1238-46.
5. Hanna WC, Ferri LE, McKendy, KM, Turcotte R, Sirois C, Mulder DS. Reconstruction after major chest wall resection: Can rigid fixation be avoided? Surgery 2011;150:590-7.
6. Losken A, Thourani VH, Carlson GW, et al. A reconstructive algorithm for plastic surgery following extensive chest wall resection. Br J Plast Surg 2004;57:295-302.
7. Mansour KA, Thourani VH, Losken A, et al. Chest wall resections and reconstruction: A 25-year experience. Ann Thorac Surg 2002;73:1720-5.
8. Lieber J, Kirschner HJ, Fuchs J. Chest wall repair in Poland syndrome: Complex single-stage surgery including vertical expandable prosthetic titanium rib stabilization – a case report. J Pediatr Surg 2012;47:e1-5.
9. Zhou F, Liu W, Tang Y. Autologous rib transplantation and terylene patch for repair of chest wall defect in a girl with Poland syndrome: A case report. J Pediatr Surg 2008;43:1902-5.
10. Leber GE, Garb JL, Alexander AI, Reed WP. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998;133:378-82.
11. Weyant MJ, Bains MS, Venkatraman E, et al. Results of chest wall resection and reconstruction with and without rigid prosthesis. Ann Thorac Surg 2006;81:279-85.
12. Robinson TN, Clarke JH, Schoen J, Walsh MD. Major mesh-related complications following hernia repair:Events reported to the Food and Drug Administration. Surg Endosc 2005;19:1556-60.
13. Lardinois D, Müller M, Furrer M, et al. Functional assessment of chest wall integrity after methylmethacrylate reconstruction. Ann Thorac Surg 2000;69:919-23.