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Reconstructive

Sternal Tumor Resection and Reconstruction Using Iliac Crest Autograft

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Background: Primary malignant tumors of the sternum are rare among bone tumors. Even with radical resection, the survival rate for sternal tumors remains low. Resection often results in significant bone defects in the chest wall, and reconstruction must provide adequate protection for pulmonary and respiratory structures. Flexible materials have historically been used for sternal reconstructions following failed sternotomies in cardiac surgery. Although these have had some success, they fail to provide adequate support for patients undergoing reconstruction secondary to tumor resection, who are otherwise healthy and active. Although rigid materials offer greater protection, they frequently cause chronic pain and respiratory complications. More recently, bone grafts have been used to reconstruct sternal defects, and the limited published reports are promising.

Methods: We present the case of a patient diagnosed with an extramedullary solitary bone plasmacytoma who underwent a sternal resection and reconstruction with an autogenous bone graft taken from the iliac crest and secured in place with 5 plates (3 sternal and 2 mandibular).

Results: At 9-month follow-up, bone marrow biopsy showed no evidence of multiple myeloma. X-ray, computed tomography, and Pulmonary Function Test (PFT) scans confirmed graft stability, and the patient has returned to normal activities.

Conclusions: Sternal resection and reconstruction is an effective method for treating extramedullary solitary plasmacytoma when radiation is ineffective. In cases of significant segmental defects, iliac crest bone graft may be a viable option for repairing sternal defects following tumor resection. *(Plast Reconstr Surg Glob Open 2020;8:e3002; doi: 10.1097/GOX.0000000000003002; Published online 18 August 2020.)*

INTRODUCTION

Sternal tumors are rare, comprising only 0.94% of all bone tumors, with the majority being sarcomas.[1] The most common sternal tumors are chondrosarcomas, followed by osteosarcoma, myeloma, and malignant lymphoma. Patients present with variable symptoms, including chest pain, palpable mass, and signs of swelling. When clinical signs cause suspicion of a sternal tumor, computed tomography (CT) scans are recommended to ascertain the extent of invasion and/or local metastases in the affected area. For a complete diagnosis, biopsy is then performed to confirm the type and grade of tumor.[2]

Although radiation therapy may be indicated, it could lead to radiation-induced sarcomas and other forms of local recurrence.[2,3] Radical or extended resection has become the gold standard for treating sternal tumors because it reduces the chances of local recurrence.[1,2,4] However, even with radical resection and reconstruction, survival rates remain low for patients with primary sternal tumors. A study of 36 patients who underwent sternal resection of primary malignant tumors reported that the overall 5-year survival rate for resection and reconstruction was 66% (low–intermediate grade: 77%; high grade: 47%).[2] Interestingly, not all mortality in the study was attributable to recurrence. Three patients

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The following devices, manufactured by DePuy Synthes (Synthes USA, LLC, Monument, Colo.), were used in the case we present: two 12-hole sternal plates, one 13-hole sternal plate, one 20-hole mandibular plate, and one 7- × 23-hole mandibular plate.

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developed a paradoxical motion in the chest wall, requiring prolonged ventilatory support and/or tracheostomy. One of these patients ultimately died due to respiratory insufficiency.[2]

Sternal tumor resection often creates large, segmental bony defects. Postsurgery defects in the chest wall can cause a floating chest wall, and reconstruction must provide protection for vital organs within the chest, maintain chest wall stability, and prevent cardiopulmonary dysfunction.[1] Ideal reconstructive materials allow for structural integrity, closely approximate normal anatomy, and sustain long-term retention in the body. These substances must also be radiopaque and easily cut, shaped, fixed, and sterilized.[2] Commonly used materials include bone allografts and autografts, muscle flaps, porous titanium mesh, omentum, steel wire, polyester fabric, silicone rubber sheets, and methyl methacrylate sandwiched between Marlex mesh.[1,4]

Although flexible materials have historically been used to reconstruct larger sternal defects, they are not without complications.[4] Often, wire, mesh, and soft-tissue flaps do not provide adequate structural support and protection of vital structures. Although they are easily cut and shaped to fit the defect, flexible coverings present a high rate of morbidity.

The majority of literature on bony chest wall reconstructions addresses failed sternotomies following cardiac surgery.[5] Although flexible materials have had some success, patients undergoing heart surgery are often elderly and physically inactive. Patients with sternal tumors, however, may otherwise be completely healthy and active. In this population, stability and protection of underlying structures are more critical in attaining meaningful recovery.

Unfortunately, flexible materials have not shown high level of success in reconstructing sternal defects caused by tumor resection.[2] In an effort to address the pitfalls associated with wire or mesh coverage, hard synthetic materials such as titanium plates have been used to reconstruct sternal defects. Although rigid synthetic plates offer protection for vital structures, they do not provide an anatomically shaped chest wall and can have infection rates as high as 17.6%.[6]

Recently, anatomic molded implants have been used in hopes of improving biocompatibility and reducing infection. Although these semi-rigid implants were successful in reducing infection, high rates of respiratory and cardiovascular complications persisted.[7]

Given the complications associated with synthetic implants, surgeons have recently turned to autogenous and allogenic bone grafts to reconstruct large defects such as those encountered poststernotomy.[8,9] Although the literature surrounding autograft reconstruction is limited, outcomes of these grafts have been promising thus far.[8,10]

In the case we present, a patient was diagnosed with an extramedullary solitary bone plasmacytoma, which was not amenable to radiation therapy. The patient then underwent sternal resection and reconstruction with autogenous bone graft taken from the iliac crest. There are currently no reports of sternal reconstruction using an iliac crest autograft in the literature.

CASE PRESENTATION

A 55-year-old man presented in clinic with a gradually increasing mass in his chest that he believed was caused by a “pop” he felt 1 year prior while lifting heavy tubing at work. In the period since the incident, the mass grew painful and interfered with normal breathing. CT scan of the chest confirmed the presence of a destructive mass in the upper sternum. Biopsy was taken from the mass, and the patient was diagnosed with an extramedullary solitary plasmacytoma without evidence of multiple myeloma.

The patient then underwent radiation therapy over the course of 1 month, with a total dose of 5000 cGy in 25 fractions to the affected area, but appeared to have no benefit. The pain in his chest continued to worsen to the point that he was having difficulty in sleeping. The patient also developed a persistent cough as the intrusive mass affected respiratory structures. After failed radiation therapy, he was referred to a surgery for sternal tumor resection.

Pectoral muscles were elevated to expose the sternum and rib cage, and the tumor was mapped (Fig. 1A). A 2-cm margin was then planned superiorly, inferiorly, and laterally onto the second, third, and fourth ribs, respectively. The sternum was divided and detached from soft tissue, removed, and sent for pathology (Fig. 1B). The subsequent sternal defect measured 10.5 cm in height, 10.2 cm in width at the inferior end, and 6.2 cm in width at the superior end (Fig. 1B).

The iliac crest was then exposed, a corticotomy was performed, and the bone graft was harvested for reconstruction (Fig. 2A). To preserve the stability of the iliac wing, only the inner table of the iliac crest was harvested (Fig. 2B).[11] Although a deep circumflex iliac artery free flap might be considered ideal for iliac crest grafting, the defect in this case was larger than the typical deep circumflex iliac artery free flap.[12,13] Given the desire to avoid donor site morbidity and to maintain the curvature of the chest wall, a nonvascularized iliac crest autograft was used for reconstruction.

The graft was then placed in the sternal defect such that the curvature of the iliac crest created a concave chest wall. The repair was fixated with 5 plates: two 12-hole sternal plates, one 13-hole sternal plate, one 20-hole mandibular plate, and one 7- x 23-hole mandibular plate (Fig. 3). The bony reconstruction was then covered with pectoral advancement flaps.

RESULTS

The patient attended regular follow-up visits with an oncologist. At 2-month follow-up, CT scan images of the patient’s chest showed a decrease in fluid posterior to his sternal reconstruction. At 5 months, he reported occasional spasms, but overall, he was asymptomatic and did not report any areas of bone tenderness.

At 8 months, the patient was able to return to normal activity (Karnofsky performance score = 90) and his pain was resolved. X-ray images confirmed that the position of the hardware was stable without change compared with previous imaging. CT scans and bone marrow biopsy showed no evidence of multiple myeloma (Figs. 4–5).

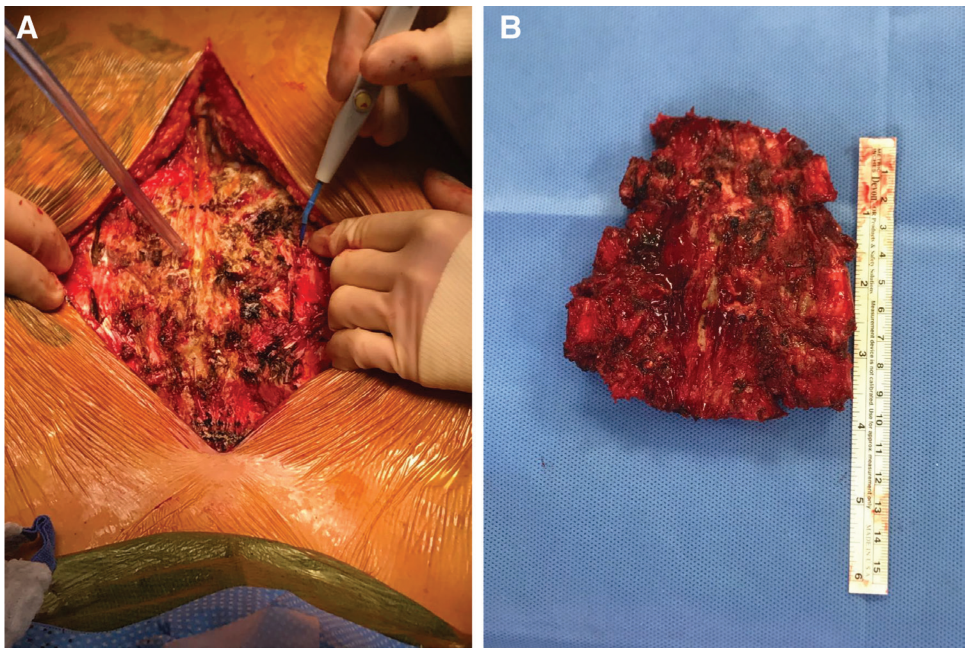

Fig. 1. Intraoperative photographs. A, Sternum exposed for tumor mapping and subsequent removal. B, Removed segment of sternum containing a destructive mass.

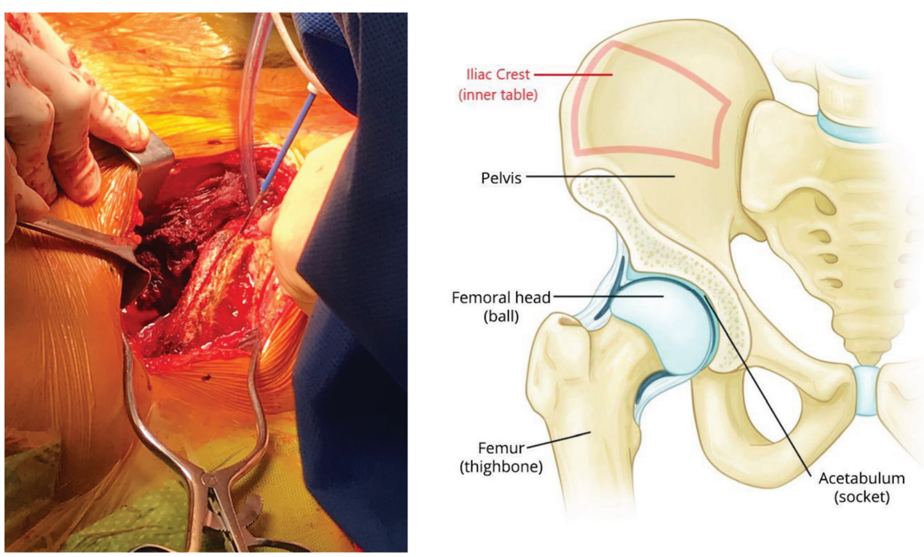

Fig. 2. Harvest of iliac crest autograft. A, Intraoperative photograph of autogenous iliac crest graft harvest. B, Diagram of the pelvis highlighting the inner table of the iliac crest.[11]

At 11 months, the patient stated that he had 100% of his daily function and was only limited in activities that require heavy lifting. He noted unrelated pain in the region of his right upper chest (there is no hardware in this region) upon waking. This pain did not persist throughout the day. The patient had regained full preoperative range of motion with no associated pain (Fig. 4). He is currently taking celecoxib, gabapentin, and diazepam.

DISCUSSION

As previously mentioned, much of what we know about sternal reconstructions comes from the field of cardiac surgery. In cardiac surgery, deep sternal wound infections secondary to failed sternotomy have a 40% mortality rate.[5] These infections can cause significant bone loss in the chest wall and require reconstruction. Defects that do not undergo reconstruction put the patient at risk of right ventricular injury and impair respiratory function, requiring the extended use of mechanical ventilation.[1,5]

Given the relative inactivity of patients typically undergoing cardiac surgery, flexible materials were first used for their utility in gaining coverage for large defects. In cases of malignant tumor resection, where many patients are

Fig. 3. Iliac crest placed and fixated with 5 plates: two 12-hole sternal plates, one 13-hole sternal plate, one 20-hole mandibular plate, and one 7- × 23-hole mandibular plate.

able to resume a higher level of activity, flexible coverings may not be adequate to produce satisfactory outcomes.[2]

As knowledge evolved and sternal reconstruction expanded to include more active populations, rigid materials were used to provide greater protection for underlying structures. The use of titanium plates can provide a high degree of sternal stability with minimal risk; however, if the extent of the sternal defects is too great, it can fail to provide enough support for the plates causing osteosynthesis failure.[5]

One study tracked titanium plate repairs in 34 patients, with an average follow-up time of 1.4 years, who underwent reconstruction for sternal dehiscence secondary to median sternotomy. Although clinical examination showed thoracic stability in 100% of patients, only 64.5% demonstrated complete or nearly complete bone consolidation on CT scans. Additionally, 35% of patients reported pain with movement and 15.1% of patients developed chronic pain. In 38% of patients, plates had to be removed due to pain or infection after an average of 7.5 months.[6]

In a study of 101 consecutive cases, Girotti et al[7] investigated the utility of their rib-like reconstructions (an anatomic molded implant composed of radiopaque acrylic and methyl methacrylate resin) in improving biocompatibility and reducing infection. Although these semi-rigid implants were successful in reducing infection (rib-like = 0%; rigid shield = 14.8%), they had high rates of respiratory and cardiovascular complications (4.5% and 18.1%, respectively).[7]

Bone grafts have the advantage of being able to incorporate with revascularization and cellular repopulation, causing an increased resistance to infection.[14] Although all reported cases have produced positive outcomes, the literature regarding the use of bone grafts in sternal defects is limited. Nahabedian et al[8] reported a case in which a 7-cm sternal defect secondary to cardiac transplantation was reconstructed using fibular allograft. Serial radiographs showed that the graft was stable and maintained space adequate for function of the transplanted heart at 4 months postoperatively. Although there were still no complications related to the graft, unrelated complications led to the patient's demise at 5.5 months.

The aforementioned developments have been especially useful in addressing primary bone malignancies because these patients are often healthy apart from their tumor and wish to return to an active lifestyle. The case we describe highlights a subset of this population and may serve as a representative example for sternal tumor resection and reconstruction.

Plasma cell neoplasia is typically diagnosed as multiple myeloma. Less than 5% of patients with plasma cell malignancies present with either solitary bone or extramedullary plasmacytoma. Solitary bone plasmacytoma is more common in men >50 years of age and primarily affects the vertebrae, occurring twice as often here as other bony sites. However, it can be found in other areas of the axial skeleton.[15] Due to its high rate of progression to multiple myeloma, at least 25% of patients with an apparent solitary lesion show evidence of disease elsewhere on magnetic resonance imaging.[15]

The traditional treatment for a sternal tumor is resection when possible; however, the recommended treatment for a solitary plasmacytoma is radiation.[2,4,15] In this particular patient, radiation therapy provided no improvement in symptoms, and surgical resection was indicated. The margins suggested for a radical resection are 3–5 cm.[1,4] Due to the local aggression of these tumors and high recurrence rate, surgical management can be difficult.[1] Postoperatively, the chest wall must be stable enough to prevent paradoxical movement, respiratory complications, and pulmonary dysfunction.[1,16,17]

The iliac crest is a strong candidate site for harvesting bone grafts because it is associated with low donor site morbidity and minimal surgical complications.[18] It is often used successfully for other procedures, including spinal fusion and nonunion surgery.[19] The curvature of the iliac crest makes it an attractive graft for sternal reconstruction. Given that even anatomical molds have failed to allow appropriate room for normal respiratory function, a concave graft could provide adequate space where other rigid implants may fail.

The use of iliac crest has been reported in a sternal reconstruction.[20] In 1993, Cara et al[20] described sternal

Fig. 4. Eleven-month postoperative photographs. The patient was able to hold all positions shown (A-D) without pain.

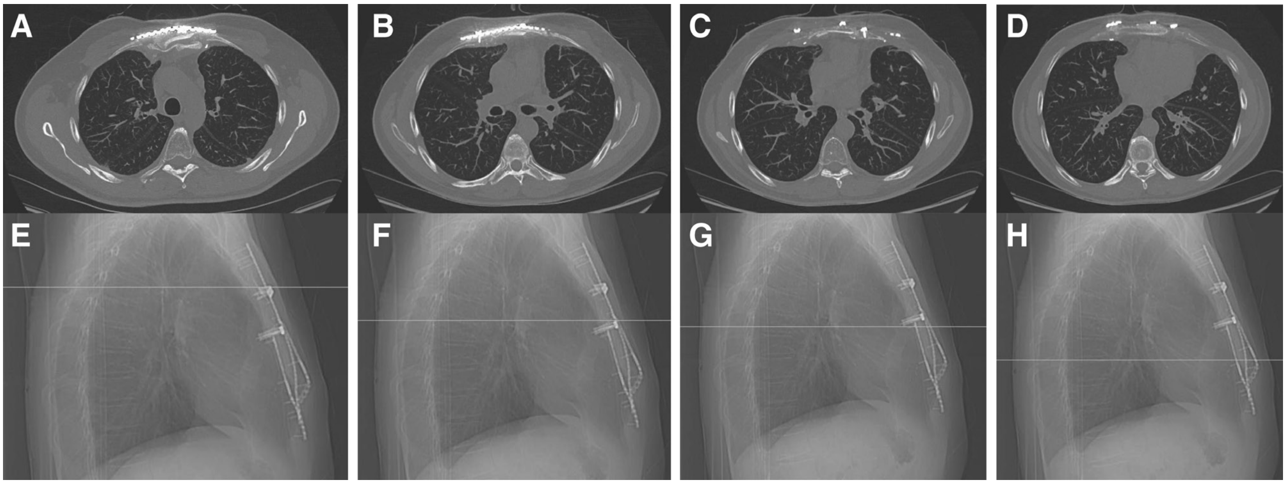

Fig. 5. CT scans showing no evidence of recurrence. Axial views are paired with lateral views to show the progression of images from superior (A and E) to inferior (D and H) within the affected area.

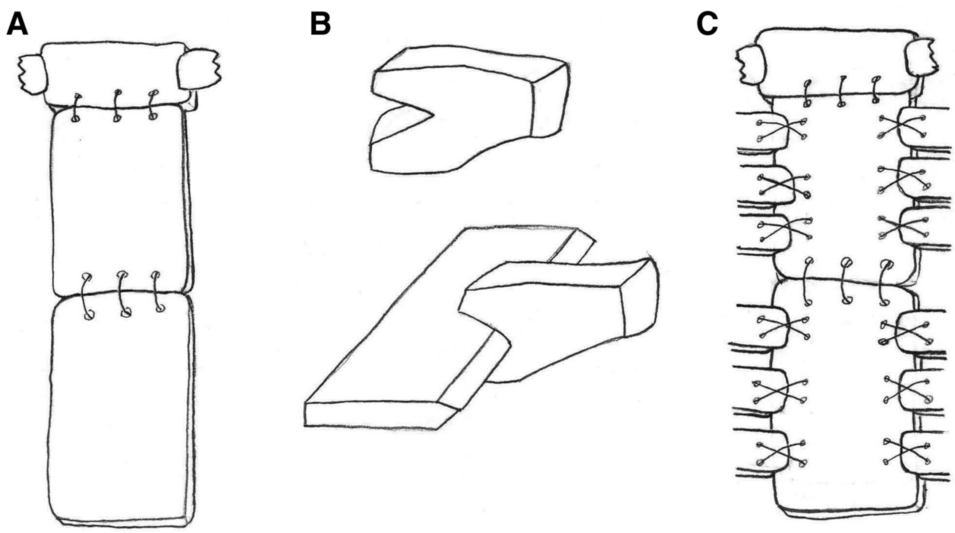

Fig. 6. Piotrowski et al. iliac crest autograft technique. A, Iliac crest grafts sutured together, with the anterior end of the graft sutured to the intact sternum. B, Wedge-shaped osteotomy formed in ribs fitted with a wedge created from the lateral edges of the graft. C, Graft tightened and sutured in place.

reconstruction with iliac crest allograft following chondrosarcoma resection. At 2 years postresection, their patient had normal respiratory function, with a well-aligned graft confirmed by CT.[20] Another case of iliac allograft usage has been reported in a defect similar to the one we present with integration and no signs of recurrence at 14 years postoperatively.[21] Although Brodin and Linden[22] did use an iliac autograft for reconstruction in 1959, the graft only partially filled the defect, and the graft was fixed in place with steel wires. This patient had chronic sensitivity in the chest, and the tumor later returned.[22]

We were able to find one report describing 2 patients with sternal defects similar to our patient in which iliac crest autograft was successfully used for reconstruction.[23] Similar to the case we describe, the internal tables of iliac wings were harvested in both cases. The grafts, measuring approximately 7 × 5 cm each, were sutured end-to-end using a 6-0 braided polyester suture, and the top of the autograft was sutured end-to-end to the intact sternum (Fig. 6A). The lateral, long edges of the graft were fashioned into a wedge shape, and the intact ends of ribs were cut with wedge-shaped incisions to receive the graft (Fig. 6B). The graft was then tightened to the ribs in a Figure-8 pattern, with 6-0 braided polyester suture (Fig. 6C). Both cases resulted in integration and uncompromised pulmonary function, as well as stability under mechanical stress.[23]

When fixating our graft, both the sternal and mandibular plating systems were used. In complex reconstructions such as the one we present, other plates of similar sizes and strengths may be beneficial when addressing uncommon reconstructive challenges. Although Piotrowski et al[23] used 2 plates to stabilize the manubrium in the first case, they did not in the second, and they believed that plate fixation was unnecessary in the technique they described. Further reports are needed to adequately compare plate fixation and the technique preferred by Piotrowski et al.[23]

SUMMARY

As shown in this case, sternal resection and reconstruction is an effective method for treating extramedullary solitary plasmacytoma, particularly when radiation is found to be inadequate. In cases of significant segmental defects, iliac crest bone graft may be a viable option for repairing significant sternal defects secondary to tumor resection.

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PATIENT CONSENT

The patient provided written consent for the use of his image.

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