Safety and Effectiveness of Cadaveric Allograft Sternochondral Replacement After Sternectomy: A New Tool for the Reconstruction of Anterior Chest Wall

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Background. **Surgical excision with wide margins, prevention of respiratory impairment, and protection of surrounding organs are primary goals in resection and reconstruction of the chest wall. We describe our experience of the use of cadaveric cryopreserved sternal allograft.**

Methods. **Eighteen patients underwent surgery. Indications for sternectomy were sternal metastases (n = 9), primary chondrosarcoma (n = 4), sternal dehiscence (n = 2), soft tissue sarcoma (n = 1), malignant solitary fibrous tumor (n = 1), and direct involvement of thymic carcinoma (n = 1). The defect was reconstructed using a cadaveric sternal allograft harvested aseptically, treated with antibiotic solution, and cryopreserved (−80°C). The graft was tailored to fit the defect and fixed in place with titanium plates and screws.**

Results. **Four patients underwent a total sternectomy, 8 a partial lower sternectomy, and 6 a partial upper sternectomy. In 14 patients, muscle flaps were positioned to cover the graft. During the postoperative course, 1 patient died of pulmonary embolism, 1 had systemic *Candida* infection, and 1 had surgical revision for bleeding at the site of muscle flap. One patient required removal of a screw on the clavicle 4 months after operation because of partial dislocation. At a median follow-up of 36 months, neither infection nor rejection of the graft occurred; 13 patients are alive without disease, and 4 patients had died. None had local tumor relapse.**

Conclusions. **Sternal replacement with cadaveric allograft is safe and effective, providing optimal stability of the chest wall and protection of the surrounding organs, even after extensive chest wall resections. The allograft was biologically well tolerated, allowing a perfect integration into the host.**

(Ann Thorac Surg 2016;■:■–■)

Sternal resection may be required for several diseases such as primary or secondary tumors, trauma, and infections (ie, radiation-induced necrosis or dehiscence after sternotomy) [1]. Chest wall resections and reconstructions present a challenge to thoracic surgeons, particularly when the anterior or anterolateral portion of the chest is involved. Primary goals in the resection and reconstruction of the chest wall are surgical excision with safety margins in case of tumors, prevention of respiratory impairment, and protection of the surrounding organs [2, 3]. The postoperative outcome after a large chest wall resection may be complicated by two major problems: respiratory failure and local infection at the level of the prosthesis [4–6]. Various techniques and materials have been used in sternal replacement. Several meshes (eg, polypropylene or polytetrafluoroethylene) have been used in the past, particularly for small defects [1, 2, 4, 7, 8], with the main problems presented by the softness of the mesh providing insufficient support for the respiratory dynamics and possible paradoxic movements, inadequate protection of the surrounding organs, and risk of infection with poor host integration.

In more recent years, rigid reconstruction using different composite materials (including plates made of methacrylate, silicone, cyanoacrylate mesh, and titanium) has been preferred, especially after total sternectomy [5, 6, 9]. Rigid materials allow for increased protection of the mediastinum, but they transform the dynamic structure of the chest wall into a fixed cage [6, 10, 11]. In addition, some composite prostheses (eg, polymethylmethacrylate) lead to a higher rate of infection, which often causes their removal [3, 5].

Another option in chest wall replacement is the use of autogenous materials. Donor sites include ribs, the

Accepted for publication Aug 23, 2016.

Presented at the Fifty-second Annual Meeting of The Society of Thoracic Surgeons, Phoenix, AZ, Jan 23–27, 2016.

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0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2016.08.093

iliac bone, and fascia lata grafts [2, 12, 13]. The main advantage of autografts is the avoidance of alloplastic materials, thereby reducing the risk of infection. The disadvantages are donor site morbidity and a limited amount of graft (bone) available for repairing broad defects.

Herein, we report our experience in sternal replacement with donor cryopreserved sternum allograft.

Patients and Methods

Between January 2009 and January 2015, 18 patients underwent sternectomy followed by anterior chest wall reconstruction using cadaveric cryopreserved sternal allograft at two academic centers (Thoracic Surgery Unit, University of Padua, and Thoracic Surgery Unit, University of Bologna, Italy). The Ethics Committee Board of both institutions approved the study. Of the 18 patients, 13 were female and 5 were male, with a median age of 59 years (range, 35 to 78). The indications for sternal resection and reconstruction were as follows: single-site metastatic disease in 9 cases (six metastases from breast cancer, one metastasis from ovarian cancer, one from renal cancer, and one from liver carcinoma), primary chondrosarcoma in 4 cases, a sternal dehiscence after cardiac surgery in 2 cases, and direct sternal involvement from thymic carcinoma, a soft tissue sarcoma, and a malignant solitary fibrous tumor in 1 patient each (Table 1).

The precise location of the tumor, the extent of sternal involvement, and the assessment of sternal dehiscence were determined by standard chest radiographs, total body computed tomography (CT), or a chest CT scan, when appropriate. Chest magnetic resonance imaging was performed in cases when there was suspicion of mediastinal or thoracic outlet involvement. The site of sternal involvement was as follows: 9 patients (50%) had the disease located in the body of the sternum, 5 (27.8%) in the manubrium and body of sternum, 2 (11.1%) in the manubrium, and 2 (11.1%) had tumors invading upper sternum and clavicles. Every patient underwent cardiopulmonary tests as part of their routine evaluation. The pulmonary function tests and the preoperative electrocardiogram were in the normal range values in all patients. A preoperative CT or ultrasound-guided needle biopsy was performed in 14 of 16 patients affected by neoplasms. The median major tumor diameter was 4.75 cm (range, 2 to 21 cm). Eight patients received preoperative induction therapy (chemotherapy, radiotherapy, or chemoradiotherapy).

Sternal Graft

When a patient is identified who would qualify for sternal allografting, we make a request for a sternochondral block to our tissue bank based on anthropometric measurements. The sternochondral block was harvested from a multiple-tissue donor using a completely aseptic technique, following Italian legislation regarding the donation. The graft was treated with an antibiotic solution with gentamicin, vancomycin, and meropenem for 72 hours at 4°C. After packaging, the allograft was cryopreserved at −80°C. This process guaranteed the sterility of the graft and the absence of immunogenic capacity. No human leukocyte antigen or ABO matching is necessary because this treatment destroys the major histocompatibility complex. The day before surgery, the graft underwent defrosting at 4° to 6°C for 12 hours. At the time of use, the graft was removed from the sterile bags and completely defrosted in a 0.9% sodium chloride solution with antibiotics.

Operative Procedure

The surgical technique has previously been described [14, 15]. Briefly, the recipient was laid in the supine position, and a midline incision was usually performed to remove subcutaneous or cutaneous tissue with a margin of at least 3 cm of macroscopically normal tissue, if possible. In most cases, a flap consisting of the pectoralis major muscles was prepared. A partial or complete resection of the sternum en bloc with costal cartilage was performed (Fig 1). The defect was reconstructed using the sternum allograft including costal cartilage. Before surgery, the graft was completely defrosted, cut, and tailored to perfectly fit the chest wall defect (Fig 2). The sternal allograft was fixed in place with titanium plates and screws (Synthes, Solothurn, Switzerland [Fig 3A]). In the case of a partial lower sternal resection, an H-shaped plate was used to fix the sternal allograft to the residual sternum (Fig 3B). In the case of a total or upper sternectomy, the sternoclavicular joint was reconstructed and stabilized in different ways. In some cases, we fixed the new manubrium to the clavicle using high-tension polyethylene sutures, recreating a new sternoclavicular joint. In 1 case, we used a titanium bar to fix the new manubrium to the clavicle, and in another case, we fixed the new manubrium to the clavicle with intramedullary nails (Synthes [Fig 3C]). Whenever possible, muscle flaps were positioned to cover the graft (Fig 3D).

Follow-Up

All patients were followed up by clinical visits, laboratory blood tests (including level of tumor markers when indicated, namely, breast cancer, ovarian cancer, hepatocellular carcinoma), and the use of imaging techniques. A total body CT scan with chest wall three-dimensional reconstruction was performed approximately 3 months after surgery in every patient to exclude recurrence of the tumor or infection, and to verify the stability and correct positioning of the graft (Fig 4). Then, for neoplastic diseases, a CT scan was performed every 4 to 6 months for the first 2 years after surgery, then yearly.

Results

Eight patients (44.5%) required a partial (lower) sternectomy with preservation of the manubrium, 6 (33.3%) received a partial (upper) sternectomy involving the manubrium, clavicle (in 2 patients), and part of the body; and 4 patients (22.2%) underwent a total sternectomy.