Anterolateral Thigh Free Flap for Complex Composite Central Chest Wall Defect Reconstruction with Extrathoracic Microvascular Anastomoses

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Background: Complex central chest wall resection defects present a challenging management problem for both thoracic and reconstructive surgeons. Although most chest wall defects can be repaired using local and regional flaps, more complicated cases require increasingly sophisticated techniques such as microsurgical free tissue transfer. This study reviews a single plastic surgeon's experience over a 4-year period with complex chest wall reconstruction using the anterolateral thigh free flap.

Methods: Five female patients who underwent the above procedure between 2004 and 2007 were reviewed retrospectively. The clinicopathologic details recorded included histologic diagnosis, extent of resection, type of skeletal defect, flap size, receipt vessels, ischemia time, and flap/donor-site complications. Skeletal reconstruction used methylmethacrylate/polypropylene mesh sandwich prostheses.

Results: The indications for surgery were metastatic breast cancer ($n = 3$), advanced primary fibrosarcoma ($n = 1$), and extensive radionecrosis ($n = 1$). The average surface area of the chest wall resection was 197 cm^2 (range, 156 to 270 cm^2). The four patients who underwent partial sternectomy and rib resection required skeletal reconstruction and subsequent ventilatory support postoperatively in the intensive care unit. The mean anterolateral thigh flap size was 188 cm^2 (range, 143 to 252 cm^2); none of the donor sites was skin grafted. There was 100 percent flap survival, and the prostheses remained fully covered in all cases after a mean follow-up of 16 months (range, 5 to 28 months). No major complications were observed.

Conclusions: The anterolateral thigh free flap is a safe and reliable option for reconstructing complicated composite chest wall defects. It therefore provides a practical alternative when regional pedicled flap options are unavailable or inadequate. (*Plast. Reconstr. Surg.* 126: 1, 2010.)

Historically, the predominant consideration in oncologic chest wall reconstruction was respiratory mechanics rather than achieving total extirpation of the neoplasm.[1] Since the first known chest wall reconstruction in the eighteenth century by Tansini,[2] the advent of antibiotics, improvements in anesthesia and critical care, and developments in ablative and reconstructive surgery have allowed extensive chest wall resection to be performed with acceptable morbidity and mortality. Common indications for such surgery include locally advanced breast cancer, radionecrosis, and primary or recurrent tu-

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mors involving multiple layers (soft tissue, ribs/sternum, and intrathoracic organs).[3] Primary or metastatic malignancies of the chest wall tend to be aggressive and often infiltrate deeply, thus necessitating extensive ablative surgery to ensure tumor-free margins.[4] The aim of reconstruction is to restore reliable and durable soft-tissue coverage to protect the intrathoracic structures; avoid disruption of respiratory functions; and provide, if possible, acceptable aesthetic outcomes.[5]

The first option is the use of locoregional muscle and myocutaneous flaps,[6,7] as they permit immediate "single-stage" chest wall reconstruction.[5–8] However, for cases in which the resections are too wide for locoregional muscle flaps or involve the supporting skeletal elements and/or the vital intrathoracic structures, the reconstructive problem becomes more complex and therefore distant, reliable, well-vascularized flap coverage is mandatory.[9,10]

Microsurgical free tissue transfers, with their superior vascularity, are particularly indicated in situations in which regional flaps will be resected during the ablative procedure or their vascular supply is compromised or too small to cover the defect.[9–11] Large central composite chest wall defects present such a challenge, especially in association with tumor recurrence and radiotherapy. Despite the large number of publications on free flap chest wall reconstruction,[9–12] there is to date a paucity of literature regarding the use of the anterolateral thigh free flap for reconstruction for this specific purpose.[13–15] The objective of this study therefore was to analyze a single plastic surgeon's (C.M.M.) experience with five central composite chest wall reconstructions using the anterolateral thigh free flap and to outline its indications and benefits.

PATIENTS AND METHODS

A retrospective chart review of five patients who underwent anterolateral thigh free flap chest wall reconstruction between 2004 and 2007 performed by a single plastic surgeon (C.M.M.) was performed. Details collected included sex, age, pathologic diagnosis, extent of chest wall resection, type of skeletal defect, flap size, recipient vessels, ischemia times, flap/donor-site outcomes, and length of hospital stay.

Preoperatively, all five patients had plain chest radiography and underwent either computed tomographic scanning or magnetic resonance imaging to evaluate the nature, location, and extent of the abnormality. In patients with suspected distant metastases, staging computed tomographic and magnetic resonance imaging scans were also obtained. The clinical tumor, nose, metastasis stage was then assigned.

Tumor resection and flap harvest were performed simultaneously by the cardiothoracic and reconstructive surgical teams to reduce the total operating time. After ablative resection, the recipient vessels were prepared on the side of the neck contralateral to the central venous line. The flap was then divided and transferred to the chest defect, and microvascular anastomoses were performed to neck recipient vessels using interrupted 9-0 monofilament nylon for the artery and 8-0 monofilament nylon running suture for the vein.

In four cases needing partial rib and sternal resection, a methylmethacrylate/polypropylene (Marlex; Ethicon, Inc., Somerville, N.J.) mesh sandwich was fabricated by the cardiothoracic surgeon (F.C.W.). The size of the defect was estimated with a ruler and a double layer of Marlex was cut to approximately 10 percent larger than this size. Next, the bone cement (methylmethacrylate) was mixed and dispensed onto one of the sheets of Marlex, where it was spread to a 2 to 4-mm thickness and contoured to the correct shape required to fill the defect. A second Marlex layer was then laid on top of it and gently pressed so that the mesh immersed itself into the still-soft bone wax (cases 1 and 2).

The whole prosthetic sandwich was then shaped to the contour of the chest wall over the base of the curve until the right degree of curvature was achieved. The sandwich was then allowed to harden. During this exothermic reaction, the whole device became very hot, and it was allowed to cool before being sewn into place. Then, 2-0 Ethibond sutures (Ethicon) were placed around the edge of the wound, with any rib ends or bone being pierced with a Brad awl so that the sutures were passed through them easily.

When this was complete, the sandwich was sewn into place using interrupted lengths of 2-0 Ethibond sutures. This gave a very secure base on which to inset the free flap. Suction drains were placed in donor and recipient sites, and prophylactic antibiotics were administered until removal of the drains.

RESULTS

Between 2004 and 2007, five patients underwent central chest wall resection with immediate reconstruction using the anterolateral thigh free flap. All patients were women, with a mean age of 61 years (range, 52 to 69 years), and the most common indication for surgery was metastasis from breast cancer ($n = 3$).

The mean area of soft-tissue resection was 197 cm^2 (range, 156 to 270 cm^2), and four patients (80 percent) required skeleton resection consisting of part of the sternum and a variable number of ribs (Table 1). This was reconstructed with a methylmethacrylate/Marlex mesh sandwich prosthesis. Flap size ranged from 143 to 252 cm^2, with an average of 188 cm^2. Microvascular anastomoses to the neck vessels were performed in an average ischemia time of 80 minutes (range, 68 to 103 minutes). No intraoperative or postoperative revision of the vessels was required, and all of the flaps were successful.

The four patients needing skeletal reconstruction were managed postoperatively in the intensive care unit for an average of 3 days (range, 2 to 7 days) before transfer to the plastic surgery ward to continue flap monitoring and subsequent care. The median subsequent stay on the surgical ward was 10 days (Table 2). None of the five patients died intraoperatively or during their hospital stay. No major complications were observed in the recipient site and, where used, the prosthesis remained covered in all cases.

Three patients had prolonged seromas of the donor site that required repeated aspiration. One patient had persistent pain at the residual fascia lata just above the knee. This required antiinflammatory drug treatment, massage, and physical therapy for a few months postoperatively. Follow-up ranged from 6 to 28 months, and two patients have died as a result of metastatic cancer at 7 and 9 months after discharge from the hospital.

CASE REPORTS

Case 1

A 64-year-old woman (patient 2 in Tables 1 and 2) presented in February of 2004 with a T2N2aM0 invasive ductal carcinoma of the left breast that was treated by total mastectomy with axillary lymph node dissection and six cycles of adjuvant cyclophosphamide, methotrexate, and 5-fluorouracil chemotherapy and 5 weeks of postoperative radiotherapy.

Three years later, she presented with a mass in the middle third of her sternum that was histologically diagnosed as a regional recurrence of the previous breast cancer. The mass grew rapidly (Fig. 1, *above, left*), and the computed tomographic scan showed bony destruction and invasion of the intrathoracic organs (pleura and left lung). A radical sternectomy with sacrifice of eight adjacent ribs was planned. During the tumor resection, both internal mammary vessels were sacrificed. Skeletal reconstruction to provide rigid stabilization of the chest wall was undertaken using composite synthetic materials made by the cardiothoracic surgeon (Fig. 1, *above, center* and *above, right*); the resulting wide soft-tissue defect that extended between the second intercostal space down to the xiphoid process was too large for repair with locoregional flaps. The defect was therefore covered with a left free anterolateral thigh flap in-

Table 1. Surgical Details of Five Patients Who Underwent Central Chest Wall Resection and Reconstruction with Anterolateral Thigh Free Flaps

Patient	Age (yr)*	Pathologic Diagnosis	Chest Defect	Defect Size (cm)	Flap Size (cm)	Recipient Vessels	Ischemia Time (min)	Flap Complications	Donor-Site Complications
1	59	Metastatic breast cancer	Sternum and 6 ribs (partial)	12 × 15	17 × 11	FA/IJV	72	None	Seroma
2	64	Metastatic breast cancer	Sternum and 8 ribs (partial)	15 × 18	21 × 12	FA/IJV	77	None	None
3	69	Radionecrosis	No skeletal	12 × 13	16 × 9	LA/IJV	81	None	Pain
4	62	Metastatic breast cancer	Sternum and 4 ribs (partial)	14 × 16	18 × 12	FA/IJV	68	None	Seroma
5	52	Primary fibrosarcoma	Sternum and 4 ribs (partial)	12 × 13	13 × 11	FA/IJV	103	None	None

FA, facial artery; IJV, internal jugular vein; LA, lingual artery.
*Age shown is age at the time of chest wall surgery.

Table 2. Recovery and Follow-Up

Patient	Intensive Care Unit Stay (days)	Long Hospital Stay (days)	Follow-Up (mo)
1	3	8	6*
2	2	9	28
3	0	6	19
4	7	17	5*
5	4	11	21

*Patient died as a result of metastatic cancer.

corporating a small segment of the vastus lateralis muscle to fill in the large thoracic dead space.

The flap was easily orientated and inset (Fig. 1, *below, left*) such that the pedicle was superior. It was passed under a subcutaneous tunnel from the chest to the neck to achieve comfortable microvascular anastomoses to the facial artery and the internal jugular vein recipient vessels (Fig. 1, *below, center*). The postoperative course was without any complications and the skeletal and soft-tissue reconstruction was adequate and stable (Fig. 1, *below, right*).

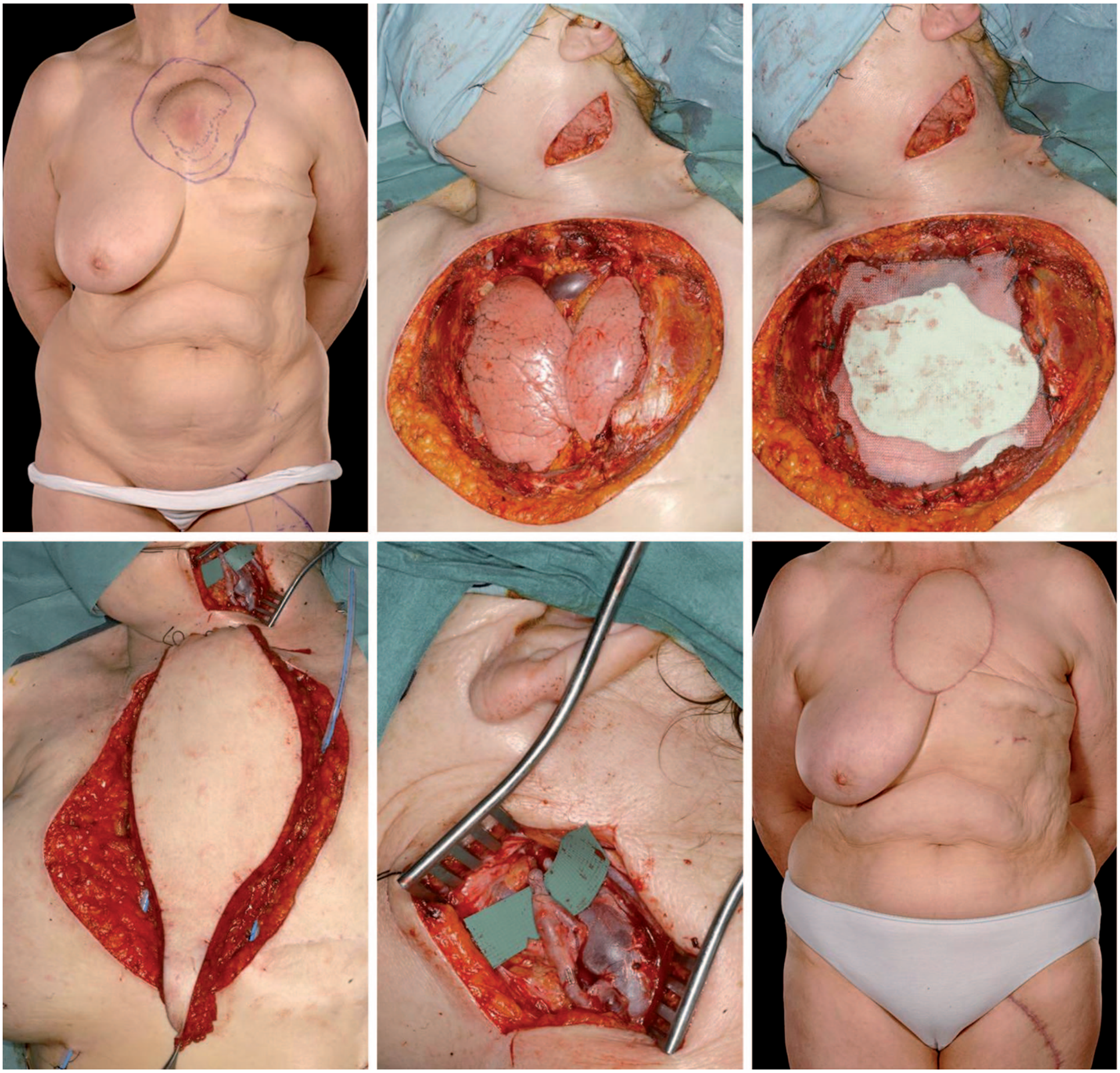

Fig. 1. Case 1 (patient 2 in Tables 1 and 2). (*Above, left*) Preoperative view of a 64-year-old woman with a large mass over the sternum indicating recurrence of the previous left breast cancer. (*Above, center*) Wide resection of the tumor. (*Above, right*) Skeletal stabilization using composite synthetic materials (methylmethacrylate/Marlex mesh prosthesis. An anterolateral thigh free flap with a small segment of vastus lateralis muscle was used to repair the soft-tissue defect. Its easy orientation (*below, left*) allows comfortable microvascular anastomoses in the neck recipient site (*below, center*). (*Below, right*) Preoperative view of the patient at follow-up 8 months after surgery.

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Case 2

A 52-year-old woman (patient 5 in Table 1 and 2) presented in January of 2004 with a large mass over the sternal manubrium that extended rapidly toward the base of the neck (Fig. 2, *above, left*). The core biopsy revealed a primitive fibrosarcoma of the chest wall. As the computed tomographic scan showed no distant metastases and chemotherapy and radiotherapy were judged unsuitable, the patient was referred for surgery. The superior two-thirds of the sternum was resected together with partial excision of four ribs. A rigid support made of Marlex mesh and methylmethacrylate was anchored to the rib remnants and clavicle, thus providing protection for the intrathoracic organs (Fig. 2, below, left). F2

A left fasciocutaneous anterolateral thigh free flap was used to cover the remaining soft-tissue defect. The recipient vessels used were the left facial artery and internal jugular vein. The hospital stay was uneventful, and the patient had a good functional and aesthetic outcome (Fig. 2, *right*).

Case 3

A 62-year-old woman (patient 4 in Tables 1 and 2) presented in April of 2006 with a left invasive lobular breast cancer (T1bN0M0). She underwent a superolateral quadrantectomy and 5 weeks of radiotherapy. After 18 months, she developed a left parasternal metastasis that grew rapidly and ulcerated. Initially, she was treated with further cycles of chemotherapy and radiotherapy, but the disease progressed and eroded into the internal mammary arteries, resulting in torrential near-fatal hemorrhage only controlled by radiologic embolization. She was then referred to the plastic surgery service for consideration of salvage surgery (Fig. 3). A computed tomographic scan revealed massive cancer infiltration of the intrathoracic structures involving the thoracic aorta, the superior vena cava, and both lungs. There were also distant metastases in the pelvis. F3

The middle third of the sternum and the adjacent six ribs were partially resected. Skeletal stabilization was achieved with our standard technique described above. The anterolateral thigh free flap, which had been harvested based on two perforators, incorporating a cuff of vastus lateralis muscle, was anastomosed to the left neck vessels (left facial artery and internal jugular vein). Postoperatively, she had breathing difficulties that required ventilatory assistance for 7 days in the intensive therapy unit. The operation was palliative but permitted the patient to live free from the fungating and intermittently bleeding, discharging, and malodorous chest wound 7 months after surgery (Fig. 4). F4

DISCUSSION

The approach to reconstructing chest wall defects is straightforward in the majority of cases.[9–11,13] There is a plethora of available techniques, and el-

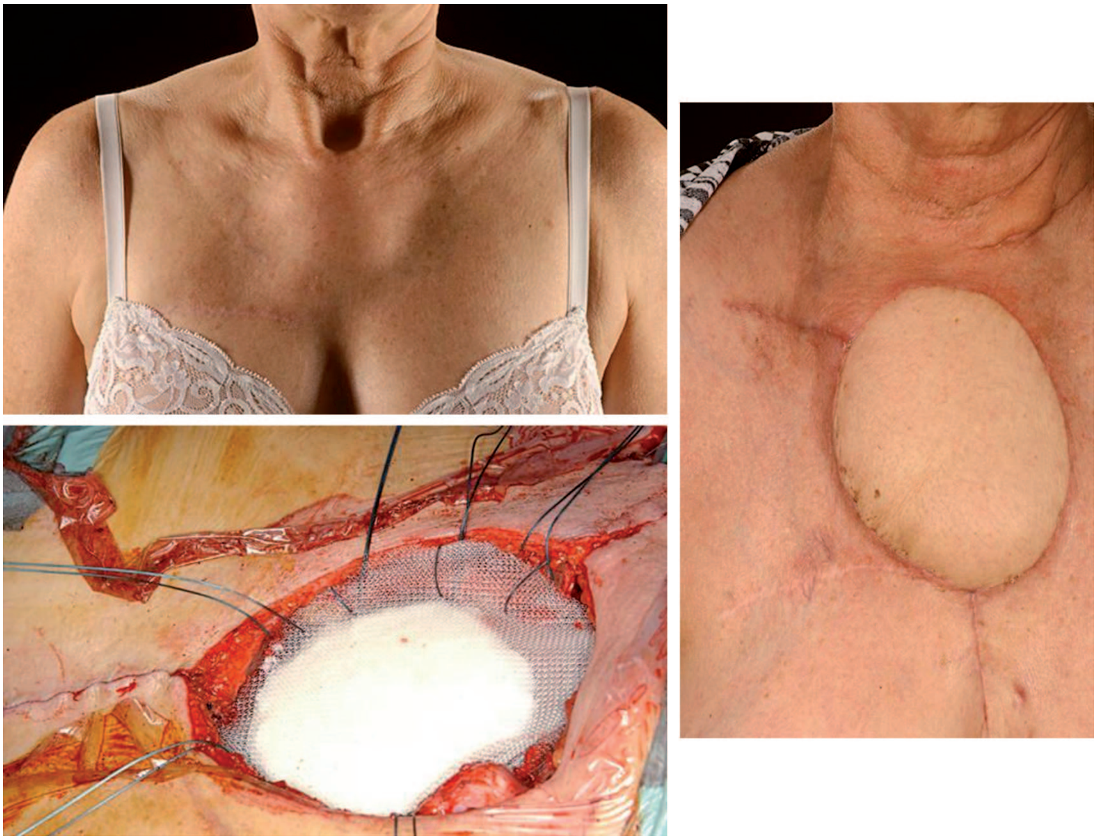

Fig. 2. Case 2 (patient 5 in Table 1 and 2). (*Above, left*) A 52-year-old woman was affected by primitive fibrosarcoma of the chest extending toward the base of the neck. (*Below, left*) Resection of the superior two-thirds of the sternum and two pairs of ribs partially. Skeletal support was achieved by methylmethacrylate/Marlex mesh prosthesis. (*Right*) Acceptable functional outcome 6 months after surgery was obtained using an anterolateral thigh free flap for soft-tissue reconstruction.

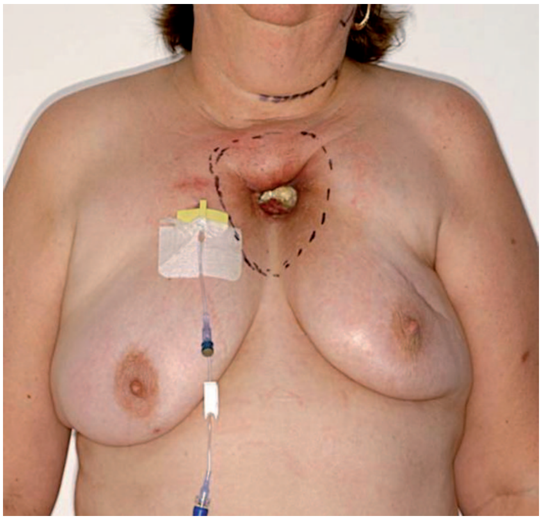

Fig. 3. Case 3 (patient 4 in Tables 1 and 2). A 62-year-old woman presented with central chest wall metastasis 18 months after the previous breast malignancy. The patient presented a nasty skin ulceration from which pus and blood were discharged because of the massive cancer infiltration into the intrathoracic space.

egant algorithms have been proposed for this purpose.[11] The critical issues in selecting the best reconstructive technique are as follows:

1. The patient's general condition and the presence of any comorbidities.
2. The tumor stage in oncologic cases.
3. Previous radiotherapy and any deleterious effects on the skin and soft tissues.
4. Size, location, and extent of the defect or proposed resection.
5. Flap and recipient-site availability.

The first step is to perform a complete and wide resection that leaves healthy, viable (and, where indicated, tumor-free) margins to which the reconstructive tissue and any prosthetic material can be anchored. Full-thickness defects of the chest wall need single-stage reconstruction to restore the mechanical stability and to cover the exposed vital intrathoracic organs. The reconstruction must provide watertight and airtight closure and should avoid paradoxical movements that could compromise breathing.[3–14] This is best achieved by the collaborative efforts of the plastic and cardiothoracic surgeons to optimize the recovery and eventual outcome. This frees up the ablative surgeon to concentrate on obtaining adequate margins to eliminate all possible malignant, contaminated, irradiated, or nonviable tissue. In our series, the cardiothoracic surgeon also undertook the skeletal reconstruction.

When embarking on soft-tissue reconstruction of the chest wall, the regional pedicled muscle flaps [vertical rectus abdominis musculocutaneous (VRAM), transverse rectus abdominis musculocutaneous (TRAM), latissimus dorsi, and pectoralis major] alone or in combination are usually the first choices. However, they have a number of limitations, including inadequate reach (especially for the central part), previous sacrifice, and precarious distal blood supply.[9,10,12–16] Any distal skin or muscle necrosis can result in exposure of the reconstructive prosthetic material used or the intrathoracic organs, potentially leading to major systemic complications.[13–17]

Central chest wall defects pose a particularly difficult problem in this respect, as a number of flaps have reach limitations. A viable robust alternative reconstructive option in this setting is the omental flap.[16–19] However, it is not easy to evaluate its status preoperatively. Moreover, the mor-

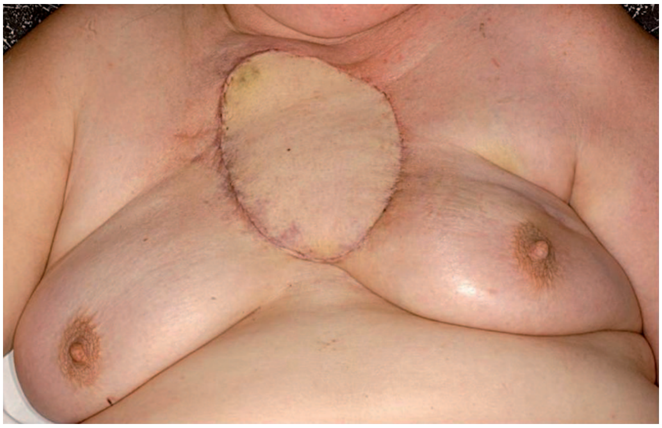

Fig. 4. Case 3 (patient 4 in Tables 1 and 2). Patient's appearance at early follow-up, 4 weeks after surgery.

bidity of a laparotomy in this group of patients should not be underestimated.[18,19]

Free flaps are the ultimate option because of their versatility. A number of free flaps have been used previously for this purpose.[9–16] An important consideration for successful microvascular reconstruction is the selection of the most appropriate recipient vessels for microanastomosis.[10,12,13] We routinely prefer to use extrathoracic vessels (i.e., the external carotid artery branches and the internal jugular vein) (Table 2). In our series, three patients presented with breast cancer recurrence, with possible metastases to the internal mammary lymph nodes, and another patient had massive sternal radionecrosis following previous radiotherapy for breast cancer. In both scenarios, the internal mammary arterial/venous blood flow could have been compromised by the preexisting abnormality. The internal mammary veins are also likely to be sacrificed during the ablative surgery, and indeed were in four of five cases. Furthermore, the extrathoracic recipient vessels had adequate diameters for easy microsurgical anastomoses, as they closely matched the caliber of the anterolateral thigh flap vascular pedicle.[9–16,18,20] We preferentially used the neck vessels because they were out of the field of previous radiotherapy. Moreover, the neck is less sensitive to the vibrations caused by the patient's breathing and cardiac pulsation, which can make microsurgical anastomosis in the thoracic space more difficult.

An additional advantage of the anterolateral thigh free flap is the freedom in orientation. Because of its long vascular pedicle and large flap size,[11,14,15,20] it can be easily tailored to the individual's defect. Indeed, the long vascular pedicle widens the choice of suitable recipient vessels in the thorax or the neck, thereby permitting optimal soft-tissue coverage while preserving the aesthetic appearance. This flap also has the right soft-tissue components (i.e., muscle, fat, and skin) and volume required to fill deep defects, despite lack of adequate bulk for skeletal support.

Because it is harvested distant from the chest resection site, it is probably oncologically safer than locoregional muscle flaps; furthermore, it does not require an intraoperative change in the patient's position, unlike other flaps such as the scapular, parascapular, and latissimus dorsi, and thus can be harvested at the same time as the oncologic resection, thereby reducing the operative time. Moreover, using pedicled or free VRAM or TRAM flaps affects intraabdominal pressure and therefore decreases the pulmonary compliance, which is often precarious in this group of patients.[17,18,21] Pedicled abdominal flaps (VRAM or TRAM) were not used because of the potential sacrifice of the internal mammary veins during the resection, and this proved to be the case in three of our patients.

However, the anterolateral thigh free flap has some drawbacks in this setting. First, it involves microsurgery, with all its attendant risks in older patients.[22] Despite its bulk, it does not provide adequate skeletal support to the chest wall. Another notable disadvantage is the poor color match, which is not a major problem at this site because it is usually hidden by clothes. Despite the above and the reported variations in vascular anatomy and technical difficulties in raising the anterolateral thigh free flap,[23] we have shown that the anterolateral thigh free flap is a practical approach that is particularly useful in reconstructing wide central complex chest wall defects.[24]

CONCLUSIONS

Our small single-operator series shows that the anterolateral thigh free flap is both safe and effective for reconstructing large complex central wall defects, as it adequately obliterated the dead space and provided reliable coverage of synthetic material with acceptable aesthetic and functional outcomes. We therefore suggest that this versatile flap should be considered as a practical and reliable option for massive chest wall reconstruction, even in the hands of low-volume operators.

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