Reconstruction of Full Thickness Chest Wall Defects

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Over the last 5 years, 14 patients were treated by wide *en bloc* resection of chest wall tumors with primary reconstruction. There were nine females and five male patients with an age range of 31–77 years. All patients had a skeletal resection of the chest wall. An average of 3.9 ribs were resected in the patients treated. In three patients a partial sternectomy was carried out in conjunction with the rib resections. Chest wall skeletal defects were reconstructed with Prolene mesh, which was placed under tension. Soft tissue reconstruction utilized selected portions of the latissimus dorsi musculocutaneous territory with fasciocutaneous extensions beyond the muscle itself. Primary healing was obtained in all patients and secondary procedures were not required. The average hospitalization was 23 days. All patients survived the resection and reconstruction and were alive 30 days after operation. In selected patients the preservation of a portion of the innervated muscle *in situ* or the transfer of the muscle with the preservation of its resting length has maintained the majority of the muscle function.

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SUCCESSFUL RECONSTRUCTION of thoracic wall defects should be provided ideally as an immediate one-stage procedure that provides structural stability and secure closure of the integument. Parham described his experience with thoracic resections for tumors of the bony chest wall in 1898.[1] In this monumental review he outlined all of the "cases of resection for malignant tumor of the thoracic skeleton" that he was able to find in the medical literature. The series began in 1778 and carried an overall 29.5% perioperative mortality rate. In his report, he expressed deep gratitude to both Fell[2] and O'Dwyer[3] for their contributions in the field of "intubation and forced respiration."

Presented at the 100th Anniversary Meeting of the Southern Surgical Association, Hot Springs, Virginia, December 6–9, 1987.

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Submitted for publication: December 10, 1987.

Classification of tumors of the thoracic wall occurred during the early 1900s. Tumors of the chest wall such as sarcomas as well as intrathoracic tumors were defined by Lund,[4] Hedblom,[5] and Harrington.[6] By 1933, reviews by authors[4,5,7,8] indicated that more than 300 cases of chest wall resections for metastases as well as primary lung, breast, and rib tumors had been performed.

Chest wall structural stability has been obtained using fascia lata grafts as described by Watson and James.[9] Autogenous rib grafts were later used by Bisgard and Swenson.[10] These were used to reconstruct a resected sternum. They made a very important technical observation about the rib reconstruction in regard to structural stability. They distracted the ribs and placed the grafts under tension to provide firm anchorage for the grafts. Maier[11] advocated large cutaneous flaps from the medial portion of the opposite breast for central defects, and laterally based abdominal wall flaps for defects of the lower thoracic region. However, it is Campbell[12] who deserves a great deal of credit for clearly defining the use of the latissimus dorsi muscle flap for reconstruction of full thickness chest wall defects. He outlined both the nerve and the blood vessel supply through the thoracodorsal system (Fig. 1). He used the muscle to reconstruct an anterior chest wall defect and resurfaced it with a skin graft.

During the 1950s refinements were made in reconstructive techniques. Blades and Paul[13] stated that "large chest wall defects . . . can be treated satisfactorily, regardless of its size." Converse et al.[14] reconstructed a radiation ulcer over the heart with an abdominal flap carried on the forearm. Myre and Kirlin[15] focused their

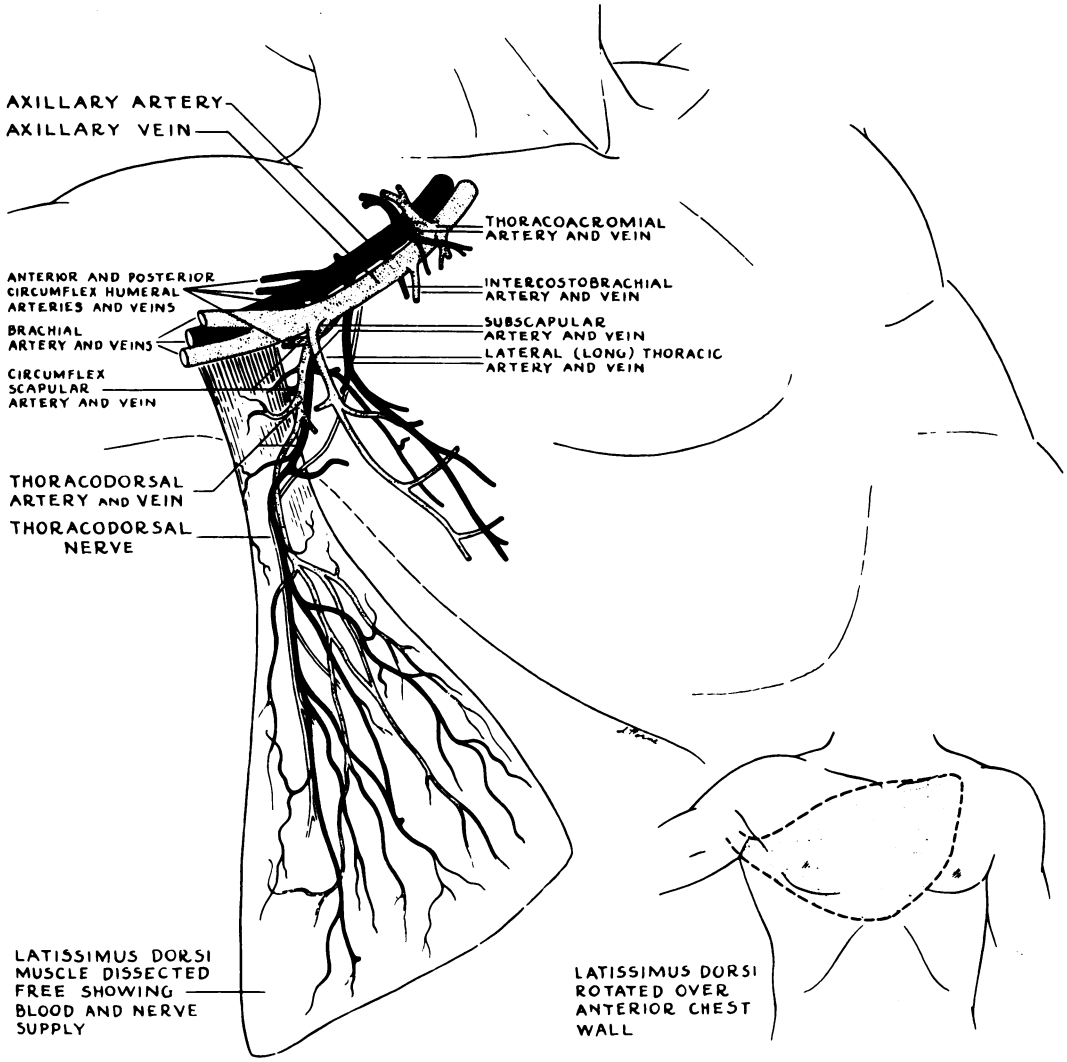
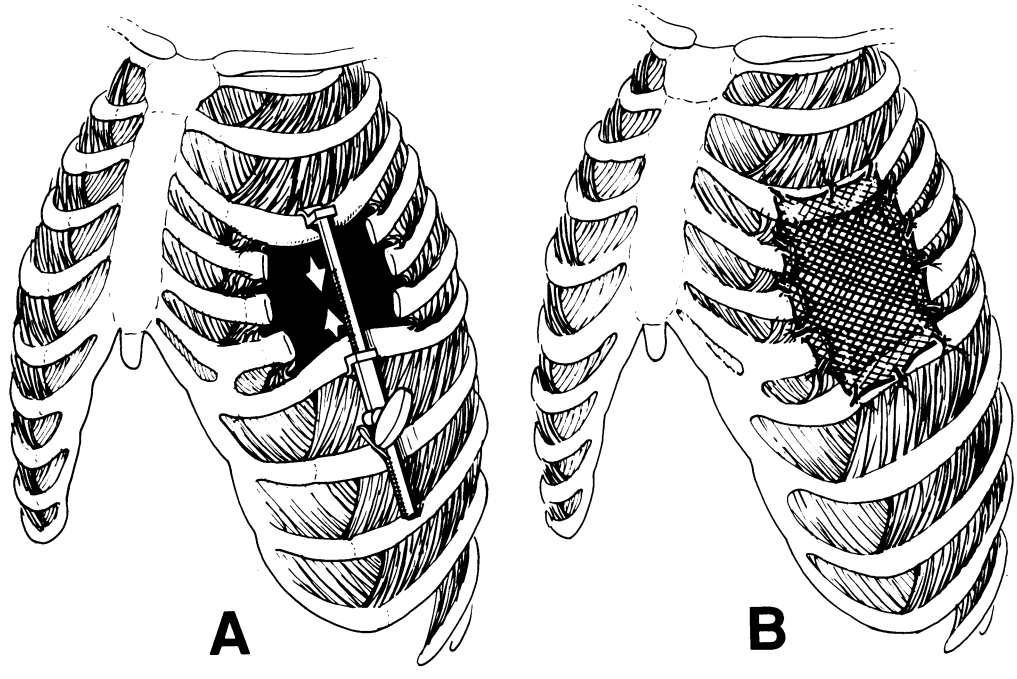


FIG. 1. Campbell clearly defined the anatomy of the latissimus dorsi muscle flap in his case report for the reconstruction of a full thickness anterior chest wall defect. (Reprinted with permission from Campbell DA. Reconstruction of the anterior thoracic wall. J Thorac Surg 1950; 19:456–461.)



FIGS. 2A and B. *A*. The placement of the Prolene mesh under tension can be greatly facilitated by securing the mesh to the surrounding thoracic skeleton with the rib approximator in place. *B*. The mesh remains under appreciable tension after the removal of the rib approximator. This helps to maintain structural stability and limit the amount of paradoxical motion after operation.

FIG. 3A. This 77-year-old woman presented with a malignant fibrohistiocytoma of the left anterior chest wall. She had had previous radiation for breast cancer.

attention on subtotal sternectomies and advocated only the use of "pectoralis fascia, subcutaneous tissue and skin."

Over the next decade the problems of chest wall reconstruction were continuously examined.[16-18] Chest wall stability continued to be a concern.[19] The use of the omentum in reconstruction was described in 1963 by Kiricuta,[20] and later refined.[21] Although a number of techniques remained in use for chest wall reconstruction, it appeared that the musculocutaneous concept was becoming the most reliable.[22] It was particularly useful after the use of irradiation on the chest wall.[23] The versatility and reliability of the latissimus muscle was

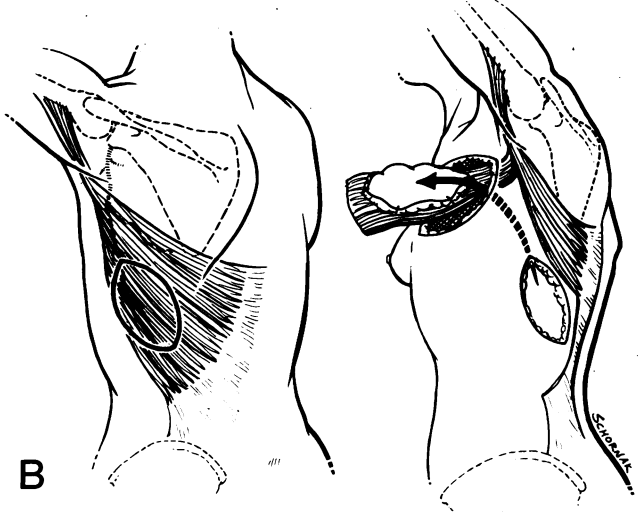


FIG. 3B. A segment of the latissimus dorsi muscle may be selected and transferred with the cutaneous island. This permits a portion of the muscle to remain *in situ* and to continue to function. The reconstructive unit is transferred through the axilla and used on the anterior chest while the donor site may be skin grafted or frequently closed primarily.

FIG. 3C. The chest wall resection is complete and the Prolene mesh has been placed under tension. The left lung is seen through the Prolene mesh.

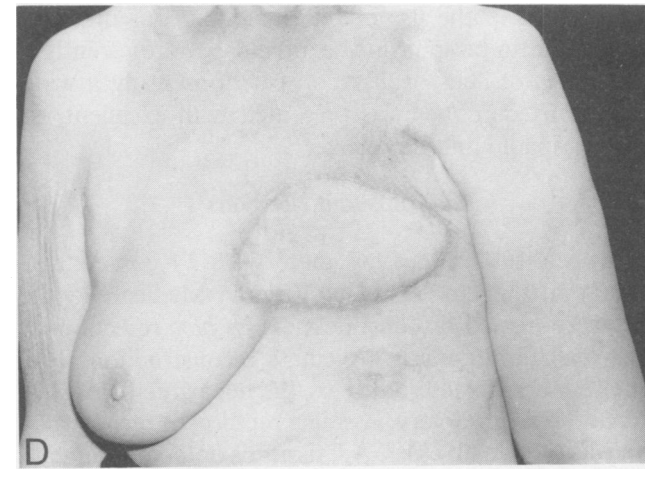


FIG. 3D. Two months after operation the anterior reconstructed chest wound is well healed. A portion of the latissimus muscle remains intact.

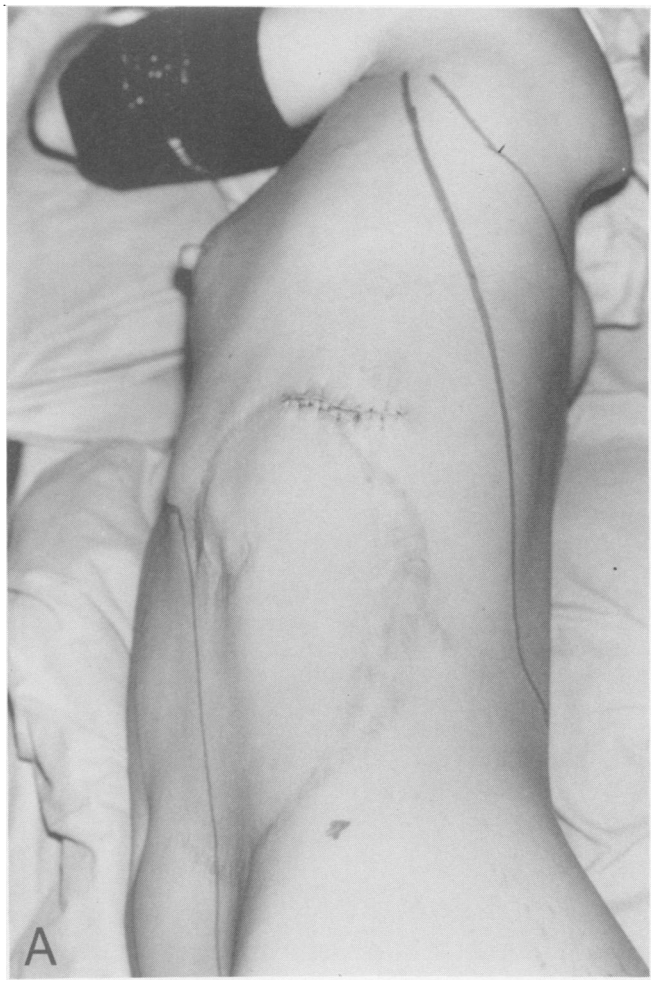


FIG. 4A. This 31-year-old woman presented after the recurrence of a condrosarcoma. The scars from the previous abdominal advancement flap are visible beneath the biopsy site.

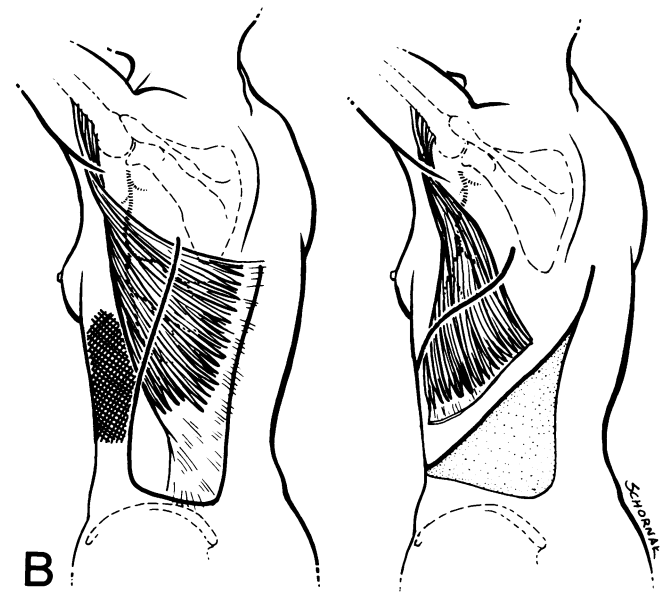


FIG. 4B. The entire latissimus dorsi muscle with an inferior extension to the level of the iliac crest was used to reconstruct this anterior and lateral chest wall defect.

FIG. 4C. The surgical defect created prior to reconstruction reveals the left lung in the upper portion of the defect and the repaired diaphragm in the lower anterior section of the surgical defect.

reported by Bostwick et al.[24] in a large series of patients. Refinements in the use of musculocutaneous units allowed them to be split into segments.[25] More recently a large series of chest wall reconstructions using a wide variety of techniques was presented with excellent results by Arnold and Pairolero.[26]

Materials and Methods

Between 1982 and 1987 there were 14 consecutive patients at the University of Virginia Medical Center who were treated by full thickness *en bloc* resection of chest wall tumors and immediate reconstruction. The patients were treated jointly by the departments of surgery and plastic surgery. A single method of reconstruction was used in all cases. A latissimus dorsi musculocutaneous flap with fasciocutaneous extensions was used as immediate coverage for the Prolene mesh (Ethicon, Inc., Somerville, NJ) that was used to obtain structural stability of the chest wall.

There were nine females and five males treated. The age range was 31 to 77 years. The mean hospitalization time was 23 days. The pathology of the lesions was varied. They included paraganglioma, malignant schwannoma, malignant fibrous histocytoma, aggressive fibromatosis, radiation necrosis, squamous cell carcinoma (2), fibrosarcoma (2), and breast carcinoma (5). The anatomic location of the defects included anterior (7), lateral (4), and posterior (3). The resection included excision of the bony skeleton in each case. The range of the ribs resected was 2 to 6 with a mean of 3.9 ribs. In three cases the resection included a partial sternectomy in conjunction with the rib resection.

Results

Each of the 14 patients had a single immediate reconstruction with a segmental or total latissimus dorsi musculocutaneous flap. Structural stability was obtained with Prolene mesh. Primary healing was obtained and no secondary procedures were required. All patients were alive at 30 days after operation, and no deaths were attributed to either the resection or the reconstruction. Follow-up study has ranged between 9 and 51 months with a mean of 27.5 months. Successful reoperation for the evaluation of a recurrence was possible in one case 8 months after operation without difficulty. Eleven patients are alive as of this writing.

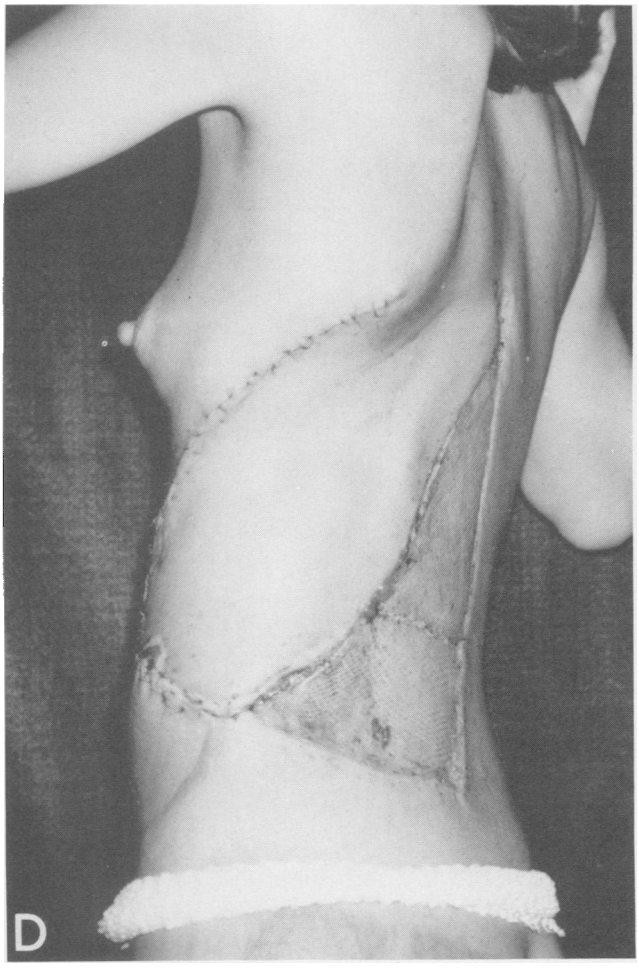


FIG. 4D. One week after operation the musculocutaneous flap is seen and the donor defect has been skin grafted.

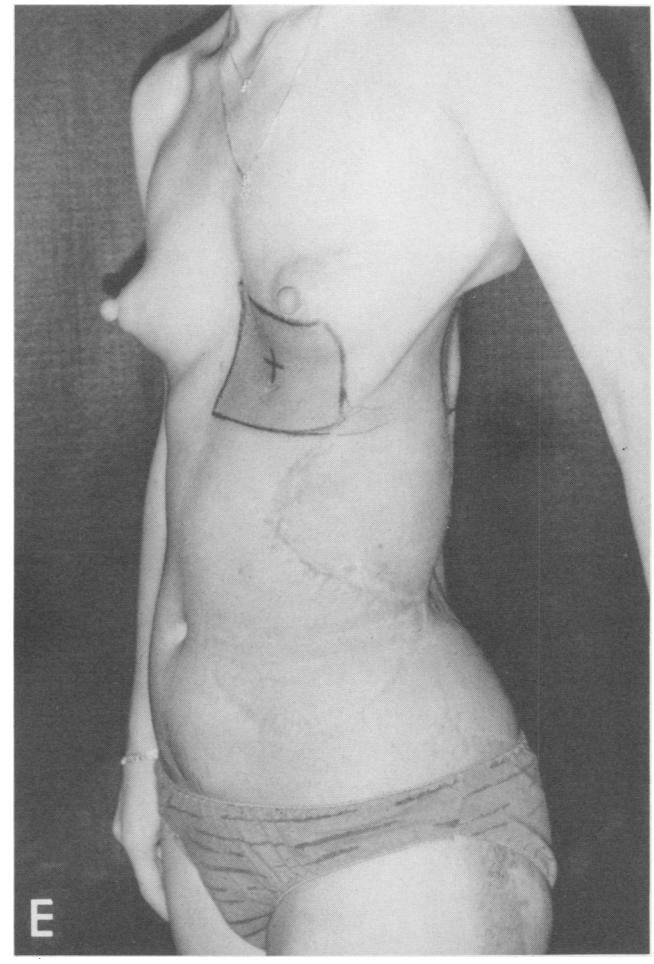


FIG. 4E. The postoperative therapy included irradiation. The anterior port outlined here. The posterior port was designed over the proximal portion of the latissimus dorsi flap. The radiation therapy was tolerated well by the reconstructive musculocutaneous flap.

Functional evaluation was obtained in two patients postoperatively. The Cybex (Cybex, Ronkonkoma, NY) data reduction computer was used and demonstrated that maintaining the correct resting length of the muscle in the transposed position or permitting a segment of innervated muscle to remain *in situ* will preserve a significant amount of total arm adduction power and endurance.

Discussion

This current report confirms the versatility and reliability of the lattissimus dorsi musculocutaneous flap.

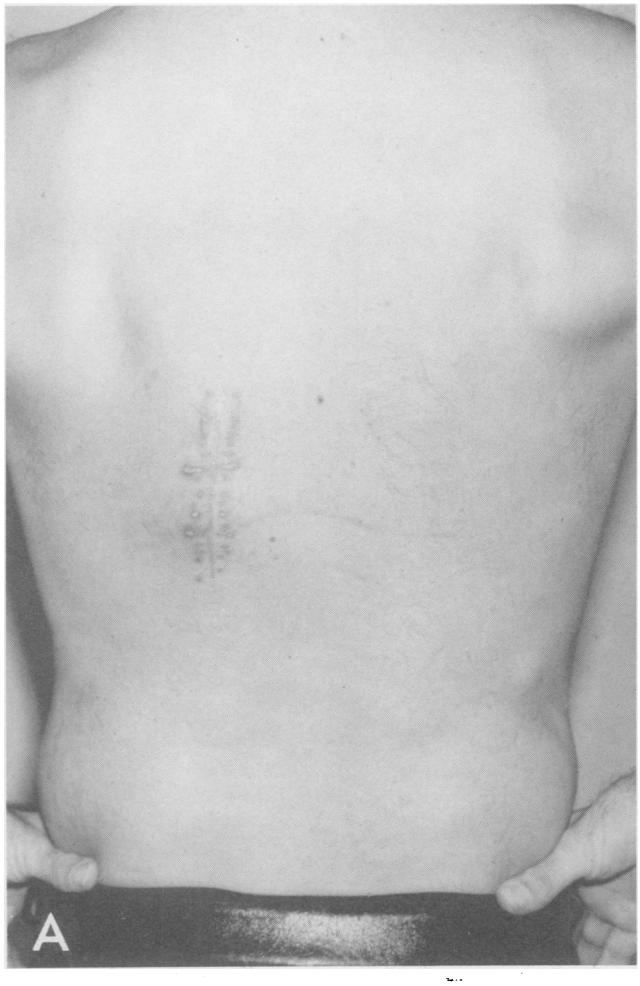


FIG. 5A. This 34-year-old man presented with a biopsy proven aggressive fibromatosis tumor. The left paraspinous location can be seen.

Fasciocutaneous extensions of the flap afford a larger reliable reconstructive unit. Dependable reconstruction allows adequate resection and optimal treatment.

The structural stability of the chest wall can be obtained with the use of Prolene mesh placed under tension. A method used by the authors places the mesh and sutures it firmly in place while the rib approximator remains in position (Fig. 2). When the rib approximator is removed the mesh increases greatly in tension. This greatly reduces the amount of paradoxical motion during spontaneous respiration. Total excision of the sternum was not undertaken in any of the cases presented, and mesh alone may not be adequate in that situation. Prolene mesh has proven to exhibit several desirable characteristics. This surgical mesh is a knitted polypropylene nonabsorbable synthetic. Because the mesh is knitted, it provides for elasticity in both directions. The fiber junctions are interlinked, and, therefore, the mesh is less likely to fracture when flexed as the more rigid metallic mesh are prone to do. The placement of the mesh under appreciable tension is essential in order to obtain structural stability. This polypropylene mesh exhibits not only high tensile strength, but also a high burst strength of approximately 250 lb/in.[2] Previous reports have shown this material to perform well in both reconstruction of the abdominal wall[27] in more than 100 patients and in reconstruction of the chest wall.[26,28]

Anterior upper chest reconstruction may be accomplished with a segmental portion of the muscle (Fig. 3). The superior or inferior portion of the muscle may be transferred with the appropriate amount of subcutaneous tissue for the reconstruction. The portion of the muscle that remains in place continues to function and aid in arm adduction. Cutaneous units of 8–10 cm in width allow primary donor site closure without difficulty.

Surgical defects of the lower anterior chest may require transfer of the entire muscle (Fig. 4). Fasciocutaneous extensions posteriorly to the midline and inferiorly to the level of the iliac crest may be required to resurface

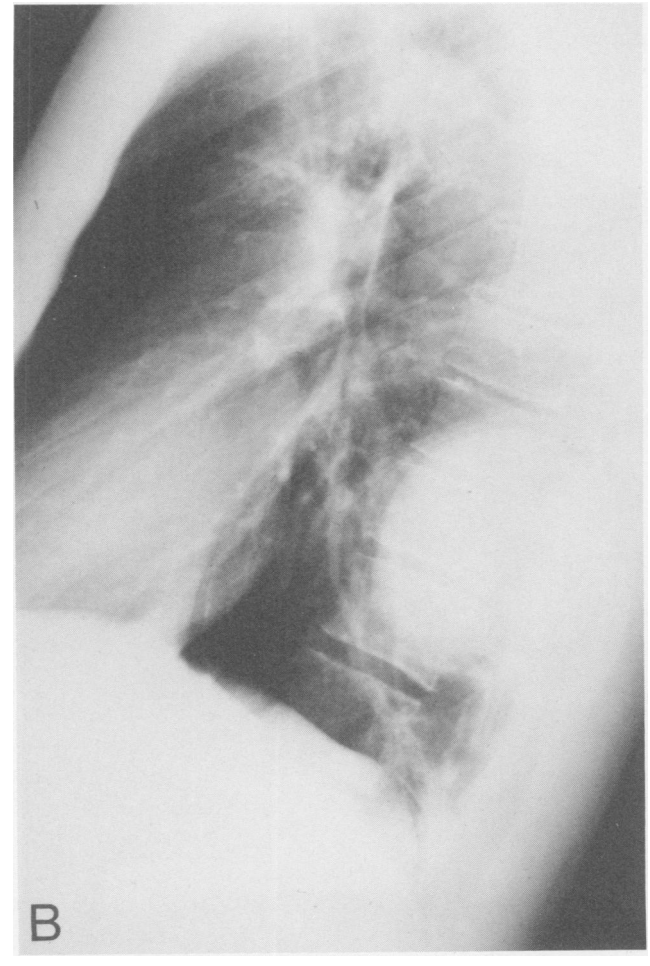


FIG. 5B. The lateral chest roentgenogram shows clearly the intrathoracic extent of the well-circumscribed tumor.

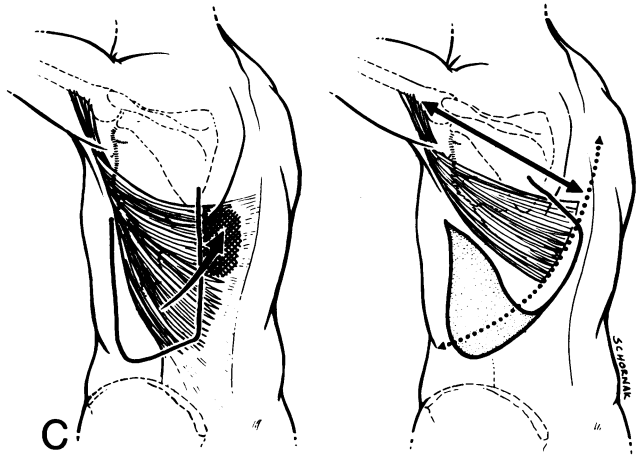


FIG. 5C. The entire origin of the left latissimus muscle was included in the reconstruction. The resting length of the muscle was marked with sutures prior to transfer. The arc of the muscle was drawn on the patient preoperatively and the distal end of the muscle was secured to the surgical defect along that arc. The tension of the muscle was adjusted so that the previously placed sutures were at the same interval after the transfer of the muscle.

the defect. If radiation therapy is contemplated in the postoperative treatment, the location of the ports should be considered. The proposed site for irradiation should be secured with well vascularized tissue. Placement of the transposed muscle in a position that approximates the normal resting length of the innervated muscle can preserve both function of the muscle and the contour of the posterior axillary fold.

Posterior chest wall defects may be reconstructed using the same principles (Fig. 5). Fasciocutaneous extensions inferiorly and anteriorly may be required. If the arc of rotation of the muscle from its insertion on the

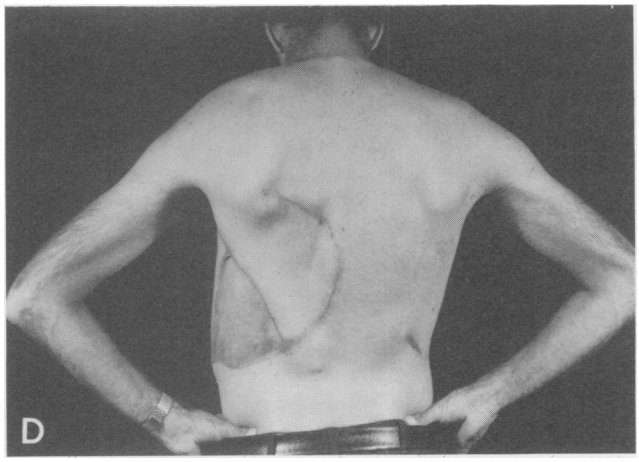


FIG. 5D. After operation the flap is well healed. The arms are in extension with forced adduction, and the preservation of the posterior axillary line by the latissimus muscle can be seen. Postoperative testing confirmed that the function of the muscle remained intact.

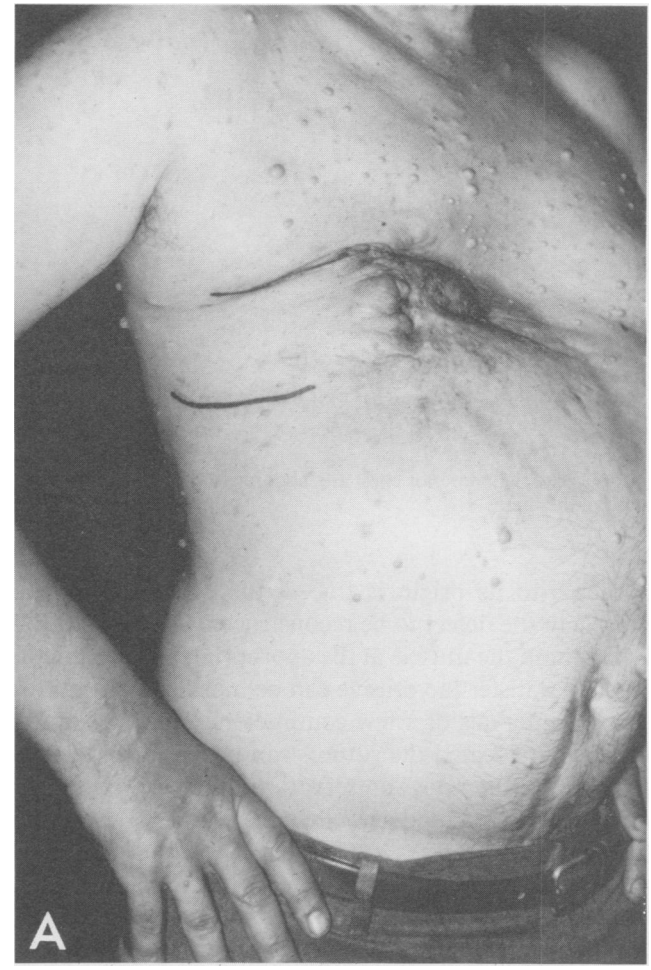


FIG. 6A. This 43-year-old man presented after several unsuccessful attempts at surgical excision of a malignant nerve sheath tumor. The site of the previous surgical scarring on the right chest can be seen at the inferior margin of the pectoralis major muscle.

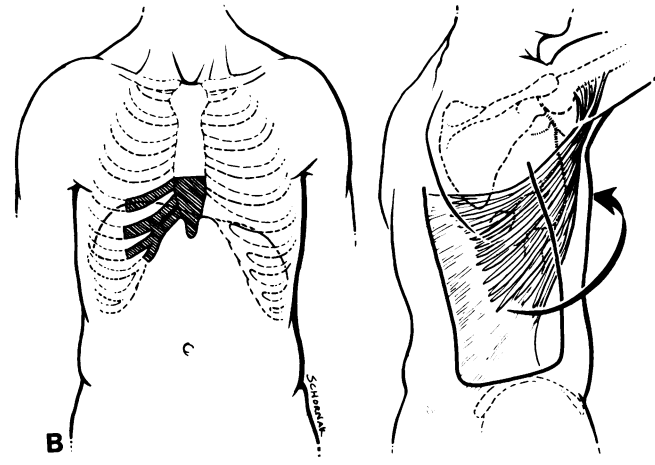


FIG. 6B. The area of resection consists of the inferior third of the sternum as well as the sixth through the ninth ribs. The entire right latissimus muscle with the anterior, inferior, and posterior fasciocutaneous extensions included was transferred to reconstruct the anterior chest defect.

FIG. 6C. The right anterior chest and abdominal defect prior to placement of the mesh.

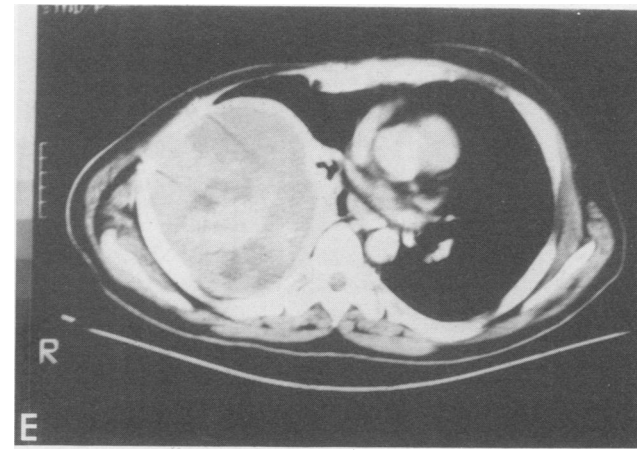


FIG. 6E. Eight months after operation a recurrence of the tumor in the right lower chest was confirmed by CT scan. The tumor can be seen extending into the right thorax.

humerus to its origin is traced, the placement of the muscle in the defect to be reconstructed can be adjusted to maintain the muscle at the appropriate resting length. Prior to transfer the muscle can be marked with sutures at fixed intervals of a few centimeters. Then, when the muscle is relocated the sutures can be readjusted to the appropriate intervals. Preservation of adduction power has been documented as well as the maintenance of the posterior axillary line contour.

Large anterior chest wall defects including a portion of the sternum may also be reconstructed (Fig. 6). The entire ipsilateral latissimus territory, which extends to the midline posteriorly, the middle axillary line anteriorly, and the iliac crest inferiorly, can be used. If a partial sternectomy is included in the skeletal resection, the reconstructive unit may extend across the midline to the contralateral side. If reexploration of the site is necessary for evaluation of a recurrence, the entire musculocutaneous unit can be elevated to allow access to the skeletal defect without difficulty. Uneventful healing can be anticipated.

FIG. 6D. After the rib approximator was removed the Prolene mesh remains under tension.

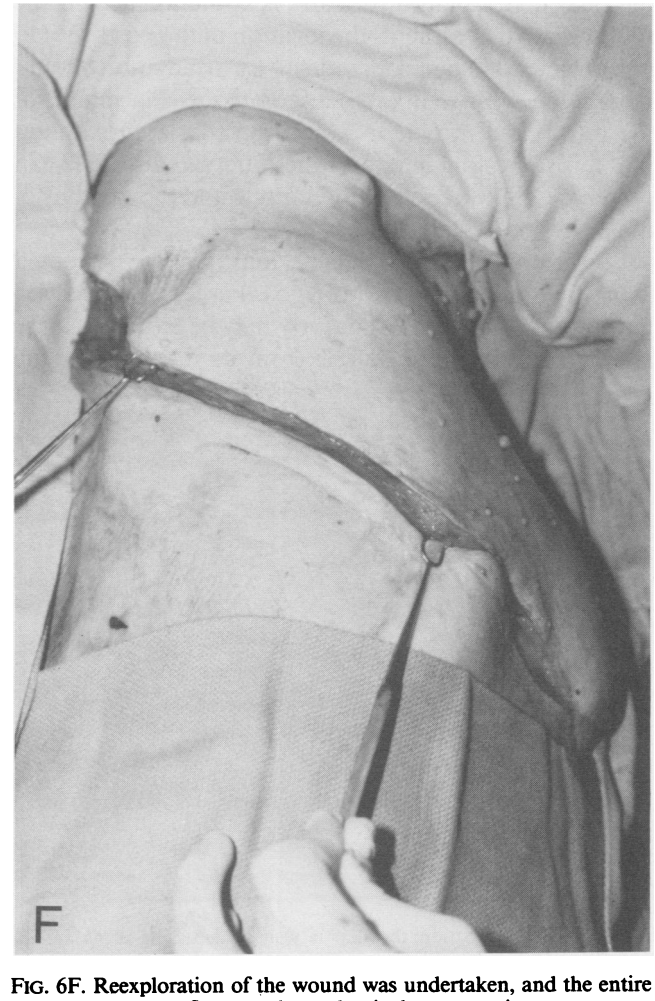


FIG. 6F. Reexploration of the wound was undertaken, and the entire musculocutaneous flap was elevated at its lower margin.

FIG. 6G. The elevation of the flap permitted evaluation both of the right chest as well as the right upper abdomen. Multiple biopsies revealed the tumor to be widely disseminated in the abdominal cavity.

Conclusion

The authors' experience with 14 consecutive patients who had full thickness chest wall excision and primary reconstruction with a single technique, latissimus dorsi musculocutaneous flap with Prolene mesh, is reviewed. The coordinated efforts of the thoracic and plastic surgeons provided optimal care for the patient. Segmental portions of the muscle that are permitted to remain *in situ* or total transfer of the muscle with the correct resting length permit continued documented adduction function of the latissimus dorsi muscle.

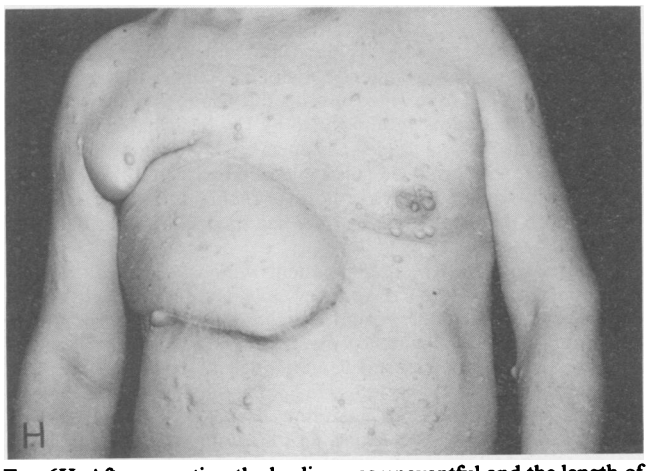


FIG. 6H. After operation the healing was uneventful and the length of the musculocutaneous flap across the midline can be seen.

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Discussion

Dr. John J. Coleman, III (Atlanta, Georgia): I appreciate the opportunity to participate in this meeting as a guest and to discuss Dr. Morgan's paper.

(Slide) During the last ten years at the Emory University Affiliated Hospitals, we have had the opportunity to deal with a number of complex thoracic defects caused either by trauma, tumor resection, or infected thoracotomy and sternotomy. Our approach has included the latissimus dorsi as an important part of this overall reconstructive plan, but we have developed, by necessity, a slightly different approach for encompassing the possibility of either reoperation secondary to tumor recurrence that might involve the previous reconstruction, or partial or complete failure of the reconstruction effort.

This approach is primarily a Plan A with a Plan B, and occasionally a Plan C, and it has been facilitated by the realization that most of these large flat muscles of the chest wall, either anterior or posterior, have an axial long blood supply, as Dr. Morgan demonstrated, the thoracodorsal pedicle in the latissimus dorsi, and also a segmental blood supply; and in the case of the latissimus, there is the paravertebral perforators of the intercostals.

This is also true of the pectoralis, and, to a lesser degree, the rectus abdominis and the trapezius. The following patient demonstrates this approach:

This is a 44-year-old woman with a three times-recurrent cystosarcoma phylloides, the resection of which required removal of four ribs, repair with Proline, and soft tissue coverage, which was accomplished by a rotation flap of the abdominal wall, based on the perforators from the anterior intercostals.

This approach allowed preservation of the contralateral internal mammary vessels, and also allowed a good repair. Preserving the vessels was, as it turned out, important because about 9 months later, the patient had a large recurrence, as might be suspected with a tumor such as this. This recurrence was addressed by a second resection and transfer of the entire abdominal wall based on the internal mammary vessels.

This approach has been used in ten major anterior chest wall resections, with the inferior epigastric kept in reserve for a possible microvascular anastomosis. So understanding the anatomy in this area allows us considerable flexibility. Our plan has generally been to start with a local musculocutaneous flap and then move, if necessary, to a regional musculocutaneous flap, and finally, to use the omentum or free tissue transfer as a last resort.

I have several questions. First, have you been limited at all by the body habitus of the patient? We have occasionally seen that the latissimus is excellent in a tall, thin patient, but in a short patient or a patient with a large barrel chest, the arc of rotation is limited. What is the safe fasciocutaneous extension of the latissimus flap, and is this limited at all by previous axillary radiation? As you mention in your manuscript, five of the patients had previous breast cancer. We have had some problems with the fasciocutaneous extension of the latissimus, and would appreciate your insight into this.

Dr. Raleigh R. White (Temple, Texas): I think the authors of this paper are to be greatly congratulated. It is a pleasure and a true benefit for me to see a paper that will help me directly in my practice when I return home. I truly appreciate the wonderful demonstration of that extended flap.

I rise to ask one specific question regarding the material that we have been using recently to repair these larger defects with a more solid material, Gortex sheeting.

It seemed good to isolate the abdominal and the thoracic cavities in these larger defects with a more solid piece of material rather than porous mesh. I wonder if you have any recent experience with that and if you would have any advice for us on its use.

Dr. P. G. Arnold (Rochester, Minnesota): I congratulate the authors on a paper that is both well presented and well written. I also appreciate having the chance to review it earlier.

In my own practice, I am in a special situation working with Dr. Peter Pairolero, who is a busy thoracic and vascular surgeon. We do a great deal of work together.

During the last ten years, we have had the opportunity to work together on about 152 of these chest wall tumors. In a third of this group we simply took the tumor out and closed the skin again after dealing with the skeletal defect.

In the 112 that were closed with muscle flaps, half of these were latissimus dorsi muscle. (In seven instances we used another muscle in addition to the latissimus dorsi muscle). Primarily we used the pectoralis muscle or another local muscle in the other half. We used a mesh if, in 84 patients, it was a clean wound (Prolene was used in 53 patients and Gortex in 32). Gortex is nice when you need a watertight closure. It costs more, but they both have advantages.

My question to Dr. Morgan is: Is the latissimus dorsi muscle flap your first choice for a chest wall reconstruction, regardless of where the tumor is located? If it is an anterior tumor, is that still your first choice?

I realize that, geometrically speaking, as long as the axis and arc is present, we can move muscles and skin from any part of the chest to any other part of the chest. Do you have a "recipe" that you go through in your own mind in deciding what to use in your reconstruction? Obviously, this presentation is about just one particular muscle flap, and I would be interested in what your other options were, and if for some reason they failed as a flap.

Dr. William D. Spotnitz (Closing discussion). I would like to thank the discussants for their excellent questions and Dr. Morgan for the opportunity of closing this paper at the 100th anniversary meeting of the Southern Surgical Association.

In response to Dr. White's question, we have not had a great deal of experience with Gortex, but we have read of its use and agree with Dr. Arnold that it is a very pliable, good material. It certainly restricts the flow of air and fluid, although it is semipermeable, and it would be the material of choice if one were trying to perform a diaphragmatic repair.

In response to Dr. Coleman, we agree that the patient's body habitus needs to be considered in the choice of this type of flap, and we agree that patients who are excessively obese and short or barrel chested may require additional consideration in use of the latissimus dorsi flap.

We have not had experience in using this flap in patients who have had axillary irradiation. As illustrated by Dr. Morgan, we have used this flap in patients who needed postoperative radiotherapy, and when the ports were specifically designed to take into account the use of the muscle flap, those patients have not had problems. However, I can't comment on those patients who have had preoperative irradiation to the axilla.

We agree with Dr. Arnold that patients who have limited rib resections on the order of 1 to 2 ribs can certainly have their skin closed and don't need these dramatic, beautiful flaps that Dr. Morgan has shown.

In closing I would like to comment that in terms of our choice of flaps, we do agree that with small anterior defects high up on the chest, we would attempt to use pectoralis major flaps first, and that inferiorly we might very well use rectus abdominus flaps. Also, as Dr. Arnold has previously recommended, we keep the omentum as an alternative and secondary means of closing defects that are not successfully treated with musculocutaneous flaps.