Chapter 10
Soft Tissue Reconstruction After Bone Sarcoma Resection

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Chapter Overview The successful outcome of bony tumor resection followed by prosthetic reconstruction can often be improved by the addition of appropriate soft tissue reconstruction using muscle or skin flaps of various types. Such flaps are particularly useful for areas likely to encounter wound-healing problems. The benefits of flap reconstruction are seen particularly in high-risk areas such as the ankle and foot, the tibial and knee region, the distal forearm and hand, the elbow, and the shoulder. The most distal parts of the extremities usually require free-flap reconstruction because of a lack of sufficient local soft tissue; however, more proximal areas can be reconstructed with a variety of local pedicled flaps, simplifying the procedures. Fillet flaps can also be used to aid in soft tissue closure if the extremity cannot be salvaged. Flap selection for specific areas is based on the size of the defect, type of coverage required (i.e., skin versus muscle), patient position, tissue availability, and surgeon preference. Proper preoperative planning and coordination between the plastic and orthopedic surgeons are critical.

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Introduction

Malignant bone tumors often require major bone and joint resections. The need for soft tissue coverage after resection is obvious when there is a large extraosseous tumor and the skin is compromised. In other cases, the value of soft tissue reconstruction with muscle and skin flaps is not so apparent. However, even when tumors are largely confined to the bone and minimally invade surrounding soft tissues, flap reconstruction is sometimes indicated. The mere ability to achieve primary closure of skin does not necessarily preclude the benefit of soft tissue repair.

Prevention of wound dehiscence is one of the primary goals of soft tissue reconstruction. Dehiscence with subsequent infection can be a disastrous complication for patients with large prosthetic and allograft implants. Such a complication often results in interruption of chemotherapy, reconstructive failure, and, in extreme cases, loss of limb. Certain anatomical locations, such as the tibial region, are known to be prone to wound dehiscence and therefore benefit from planned soft tissue reconstruction. The susceptibility to wound dehiscence may be increased in some patients by preoperative chemotherapy, which compromises the patients' nutritional status and resistance to infection. Pediatric patients, especially under the age of 12 years, tolerate wound complications poorly, and every effort should be made to minimize the possibility of repeated dressing changes, immobility, hospitalization, and reoperation in these patients.

At MD Anderson Cancer Center, soft tissue repair is performed frequently after major resections of bone tumors. The bone and joint reconstructions are complex and typically involve large allograft and prosthetic replacements. Coverage of vulnerable implants with well-vascularized soft tissue is an essential part of our surgical philosophy. Additional indications for flap reconstruction include intraoperative and postoperative swelling and mismatches between host bone and implanted materials. The most commonly used soft tissue reconstruction technique involves pedicled muscle flaps with skin grafts. Free-tissue transfer is utilized when defects are larger and more distal in the extremities.

Wound Defects That Require Soft Tissue Repair

Skin and soft tissue resections are frequently a necessary part of removing bone sarcomas. Large tumors may cause thinning of the overlying skin, which may be susceptible to necrosis during resection. For tumors with close proximity to skin or direct skin invasion, varying degrees of cutaneous resection may be required to obtain adequate margins.

Certain watershed regions are at higher risk of soft tissue loss due to poor perfusion, and these areas are more likely to require reconstruction. These sites include the ankle and foot, the tibial and knee region, the distal forearm and hand, the elbow, and the shoulder. Loss of skin in these areas results in more tension on the surgical closure and increases the likelihood of postoperative wound complications. Even minimal skin resection in these areas may precipitate the need for reconstruction because there is little available skin laxity and vital structures are easily exposed.

Resection of a sarcoma with subsequent bone and joint reconstruction is typically a lengthy procedure, requiring 8 h or more in some cases. The resultant soft tissue swelling during these long procedures may result in the inability to primarily close the surgical site without tension. Such an occurrence is difficult to predict preoperatively, apart from knowing which anatomic locations are at higher risk. Tension on the operative closure can lead to skin-edge ischemia and possible wound dehiscence. This situation is especially worrisome in areas with little or no muscle coverage over the implant, such as the tibial region, elbow, and ankle.

At MD Anderson, patients with tumors in areas deemed at high risk obtain plastic surgery consultation before their tumor resections. This consultation allows preoperative discussion with the patient about possible soft tissue reconstructive options, obviating the need for most intraoperative consultations when wound closure difficulties arise. This practice avoids problems associated with plastic surgeon availability, adequacy of informed consent, and other preparations for the case.

Finally, it is worth noting that the size of the implant has an impact on the size of the wound defect. Allografts tend to be more bulky and less predictable than metallic prostheses, and thus extra care must be exercised in the selection of allografts. Comparison of the donor allograft X-ray to the host X-ray with internal size markers is essential to verifying a good match. A larger-than-expected allograft may result in a bulkier implant and may increase the tension on the soft tissue repair. In some cases, a larger flap or a free flap may become necessary. This situation is particularly likely in the proximal tibial region, which is frequently reconstructed with allograft–prosthetic composites. In areas at high risk for wound complications, there is little room for error with the soft tissues, especially in the setting of intraoperative edema.

Types of Soft Tissue Coverage

Rotation (Pedicled) Flaps

The mainstay of flap coverage for bone sarcomas is the pedicled muscle flap. Although local skin flaps can sometimes be used for smaller defects, they often fall short of complete coverage of the implants used for bone reconstruction. Muscle flaps are more durable and robust. They are available in most anatomic sites, are relatively quick to harvest, and provide excellent vascular coverage for the implants. A skin graft is usually combined with the muscle flap to achieve closure of the wound.

Gastrocnemius Flap

One of the most common pedicled flaps is the gastrocnemius muscle flap (Figs. 10.1 and 10.2). It is a robust flap, is relatively easy to raise, and provides coverage for the

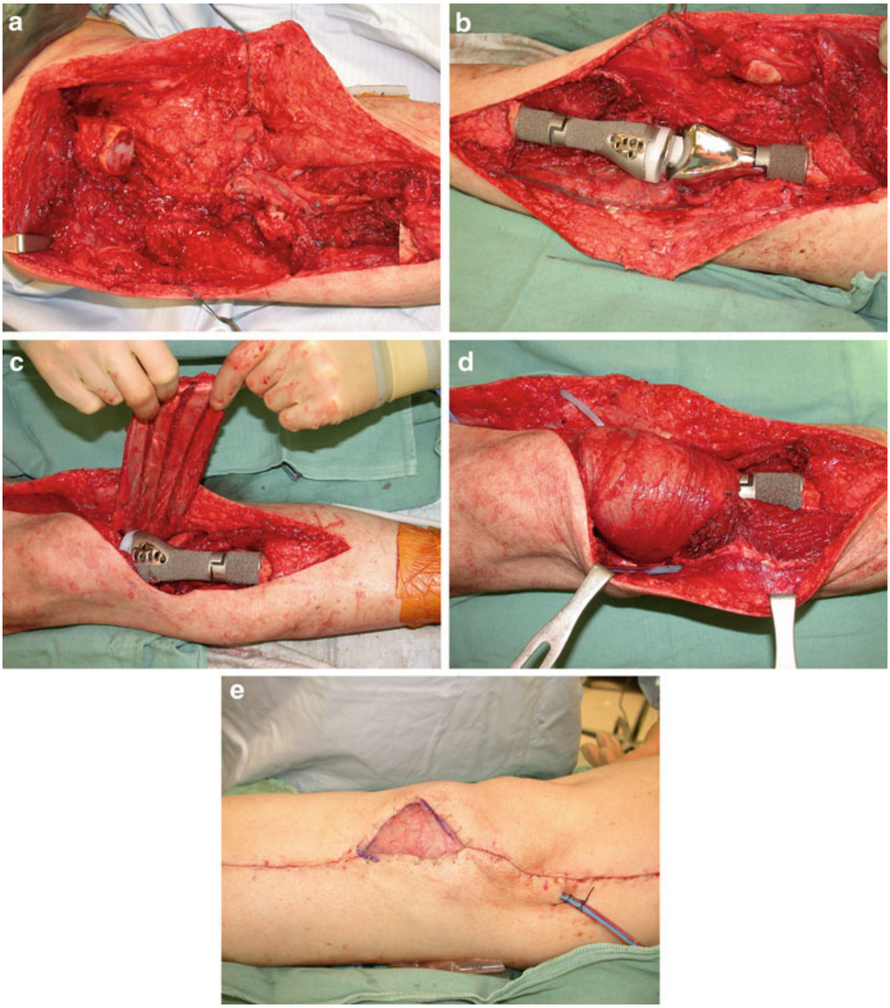

Fig. 10.1 Gastrocnemius muscle flap coverage of a prosthesis after resection of a tibial neoplasm. (**a**) The bony defect after sarcoma resection. The femur is seen at left, the tibia at right. (**b**) The prosthesis in place. (**c**) The gastrocnemius muscle flap elevated. Note that the fascia has been scored to allow a greater area of muscle coverage. (**d**) The flap in place, covering a majority of the prosthesis. (**e**) The closed wound, incorporating a split-thickness graft.

lower knee and upper third of the tibia. This area is particularly prone to wound-healing problems because of the thinness of the skin that overlies the tibia. Furthermore, our practice of using allograft–prosthesis composites for reconstruction of the proximal tibia demands a very high success rate for wound healing.

The medial head of the gastrocnemius muscle is utilized for reconstructive flaps much more frequently than the lateral head. The medial head is longer than the lateral head in most patients and can be harvested and inset without dissection or

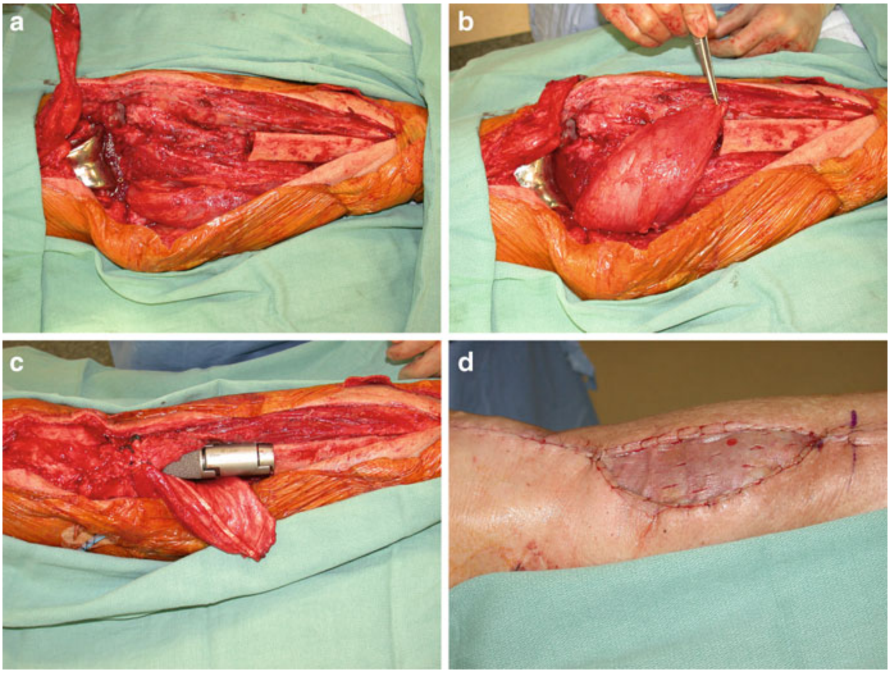

Fig. 10.2 Elevation of a gastrocnemius muscle flap prior to final placement of a prosthesis and subsequent inset of the flap. (**a**) The bony defect after sarcoma resection. The tibia is seen at right. (**b**, **c**) A gastrocnemius flap raised to cover the prosthesis. (**d**) The closed wound, incorporating a split-thickness graft.

exposure of the peroneal nerve near the fibular head. The lateral head of the muscle can be used for defects on the same side of the leg, but its arc of rotation is limited by the head of the fibula. Also, postoperative peroneal nerve palsies have occurred with lateral head use, likely from postoperative swelling of the soft tissues near the nerve. If this complication occurs, it may take several months to resolve, especially if postoperative radiation therapy is administered to the region.

At MD Anderson, the orthopedic oncologist works closely with the plastic surgeon for these complex bony and soft tissue reconstructions. For proximal tibial lesions, for example, after the tumor has been resected and before the prosthesis has been inset, the plastic surgery team is called to evaluate the degree of edema and soft tissue defect, if any.

The gastrocnemius muscle flap is often raised through the open incision anteriorly by the plastic surgery team while the orthopedic team prepares the implant. This methodology has several advantages. First, there is no additional donor-site incision on the back of the calf. Occasionally, a small incision is made over the Achilles tendon to release the medial or lateral gastrocnemius musculotendinous junction, but this incision is much smaller than the traditional stocking-seam incision used to harvest the muscle when the host tibia or a prosthetic is in place. Second, the mobilization of the muscle is much easier when the patient is in the supine position with the distal leg flailed. Careful rotation of the leg allows for easier visualization and delineation of the two muscle bellies and aids dissection of the sural nerve out of the midline raphe. Also, the proximal dissection near the popliteal fossa toward the origin of the muscle is much easier. This approach facilitates release of the muscle origin if needed for increased flap excursion while reducing the risk of injury to the adjacent vascular pedicle. Lastly, the overlap of the flap harvest and implant preparation shortens the length of the operation. The speed of postoperative healing and the quality and hardiness of the wound closure are enhanced using these techniques to treat the problematic tibial region.

Pedicled gastrocnemius muscle flaps can be used to close defects in the distal thigh and proximal knee regions as well, but their reach to these areas is more limited. The bulk of the muscle does not reach significantly above the knee, and the narrower and less robust distal muscle at the musculotendinous junction is left to fill more proximal defects. Because of these limitations of the gastrocnemius muscle, more proximal or larger soft tissue defects at or above the knee usually require free-tissue transfer.

Soleus Flap

Another muscle that can form a pedicled flap for leg reconstruction is the soleus. This muscle can be used to cover soft tissue defects over the middle third of the tibia. This flap is useful alone for segmental defects in which allograft reconstruction is used or in combination with a gastrocnemius flap for longer areas of exposed bone. For reconstructing large defects, no more than half the normal muscle contribution to the Achilles tendon (i.e., one hemisoleus and one head of a gastrocnemius flap from the same side) should be sacrificed to maintain adequate strength for plantar flexion. If more coverage is required, a free-tissue transfer should be used.

Latissimus Dorsi Flap

Besides the tibia, another potential problematic area is the shoulder. Soft tissue coverage is preferable if a significant portion of the deltoid muscle is resected. Prominence of an implant in this area can lead to wound dehiscence and exposure if there is insufficient soft tissue beneath. The latissimus dorsi myocutaneous flap is well suited to coverage of implants in the shoulder and proximal humerus. The muscle is easy to raise, reliable, and large enough to both cover the implant and fill adjacent dead space. It is long enough to be used for both anterior and posterior defects of the shoulder. The skin paddle can usually be placed to allow insetting directly over the top of the shoulder, where maximal soft tissue padding is needed (Fig. 10.3). Often the tumor can be removed and both bony and soft tissue reconstruction can be performed with the patient in the lateral position, facilitating flap harvest and reducing operative time. Again, close communication between the orthopedic and plastic surgery teams is crucial to maximize efficiency and minimize operative time.

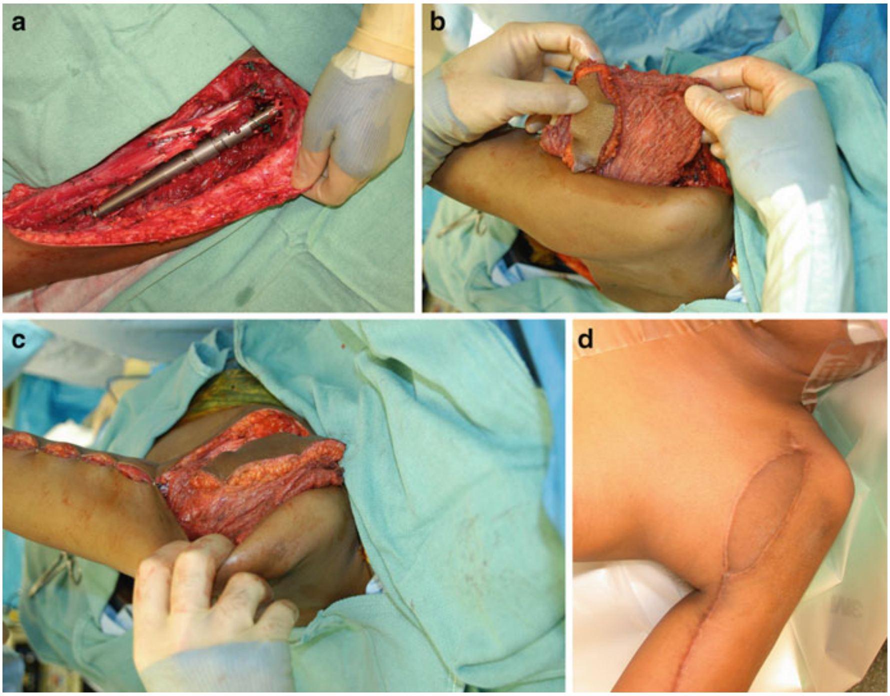

Fig. 10.3 Coverage of a humeral prosthesis with a latissimus dorsi myocutaneous flap after sarcoma resection. (**a**) A prosthesis in place after resection of an osteosarcoma of the humerus. (**b**, **c**) Placement of a latissimus dorsi myocutaneous flap to cover the prosthesis and fill the defect. The shoulder is seen on the right. (**d**) The healed flap.

Pectoralis Major Flap

The pectoralis major muscle is another option for use in reconstructing shoulder defects. Because its vascular pedicle is located anteriorly under the clavicle, the muscle is often available even if the tumor extends into the axilla and the latissimus dorsi pedicle has been compromised. The muscle itself is shorter than the latissimus dorsi, with a more restricted arc of rotation. The pectoralis major muscle is best suited to anterior defects of the shoulder, supraclavicular defects, and axillary reconstruction. For female patients who need a skin paddle, the pectoralis donor site may be cosmetically less acceptable because of possible deformation of the breast.

Radial Forearm Fasciocutaneous Flap

The elbow region is also an area in which thin skin overlying a prosthesis can be prone to healing problems. With few expendable donor muscles in the forearm, the pedicled flap of choice for elbow reconstruction is the radial forearm fasciocutaneous

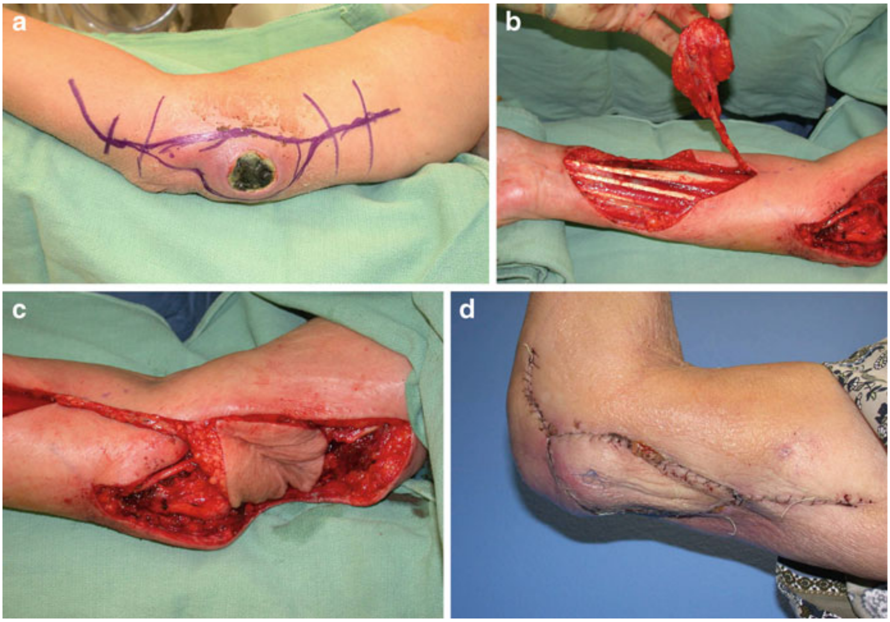

Fig. 10.4 Use of a pedicled radial forearm fasciocutaneous flap for coverage of an elbow soft tissue defect after sarcoma resection. (**a**) A large soft tissue sarcoma of the elbow. (**b**) A radial forearm fasciocutaneous flap elevated on its vascular pedicle. (**c**) The flap, prior to tunneling, shown reaching the defect. (**d**) Final closure.

flap (Fig. 10.4). It is thin but robust and large enough to cover small- to medium-sized defects of the elbow region. Its long pedicle allows it to reach medial, lateral, and dorsal defects without tension. Use of this flap does require both a skin graft for closing the donor site and sacrifice of the radial artery, but these drawbacks are well tolerated in most patients. An Allen test is used preoperatively to assess for a patent ulnar artery and vascular arch in the hand. A positive Allen test is lack of blood return to the hand after 5–6 s following release of the ulnar artery. While reassuring if the test result is negative, a positive result does not preclude the use of a radial forearm fasciocutaneous flap. Intraoperatively, vascular sufficiency on the radial side of the hand is carefully assessed before dividing the radial artery. The radial artery is explored and occluded with a vascular clamp. Then, after allowing time for equilibration, blood flow to the hand and thumb can be assessed clinically by capillary refill or handheld Doppler unit. Though rarely necessary, the radial artery can be reconstructed with a vein graft if circulatory flow to the thumb is determined to be inadequate.

Free-Tissue Transfer

Free flaps are commonly required for large soft tissue defects. In addition, moderate-sized wounds of the hand, distal forearm, distal leg, ankle, and foot often require free-tissue transfer. The elbow and knee regions may require free flaps if pedicled flaps are inadequate or unavailable, owing to the size of the defect or the loss of viable tissue (e.g., due to previous surgery or regional radiation therapy). Free-tissue transfers are significant soft tissue reconstructions and add considerable time and complexity to the operation. Nevertheless, a high success rate can be achieved when a skilled microsurgery team is combined with excellent nursing and support personnel.

In most instances, a muscle is utilized for the free flap, and it is covered with a split-thickness skin graft. Donor muscles include the rectus abdominis, latissimus dorsi, gracilis, and serratus anterior muscles. The choice of donor muscle depends on several factors: the size of the defect, type of coverage required, patient position, muscle availability, and surgeon preference.

Small- to medium-sized defects in the extremities can be covered with a rectus abdominis or gracilis muscle flap. These flaps can be harvested with the patient in the supine position. Larger defects may require a latissimus dorsi flap, requiring an intraoperative turn of the patient, unless the resection can be performed with the patient in the lateral position.

If the patient has a recurrent tumor, and a free flap was used in the original resection, the choice of a second free flap may be limited. For example, both rectus muscles should not be sacrificed because the result would be significant abdominal wall weakness.

Certain muscles have characteristics that make them desirable for certain regions of the extremities. The gracilis muscle (Fig. 10.5) works well for ankle/foot and wrist/hand reconstruction because it covers a majority of defects in these areas, atrophies significantly, and can be harvested from the ipsilateral leg, limiting donor-site morbidity. The rectus abdominis (Fig. 10.6) is an excellent choice for moderate tibial and knee defects that cannot be accommodated by gastrocnemius flaps. The latissimus dorsi muscle is generally reserved for larger knee, distal thigh, and shoulder defects. Serratus muscle flaps have the benefit of a very long vascular pedicle while allowing preservation of a functional latissimus muscle. In patients who receive preoperative radiation, this long pedicle is used to locate the microvascular connections away from the radiated and/or reconstructed vessels in the affected portion of the extremity.

Several types of free skin and fasciocutaneous flaps are also available for reconstruction after bony tumor resection. These include the free radial forearm flap, anterolateral thigh flap, and scapular flap. Such flaps (e.g., the radial forearm flap) can be used when a thinner, less bulky flap is desired. They can also be chosen in situations dictated by positioning and/or the lack of suitable donor muscles (e.g., an anterolateral thigh flap might be used for a patient in the supine position who does not have available abdominal muscles). Free skin and fasciocutaneous flaps have

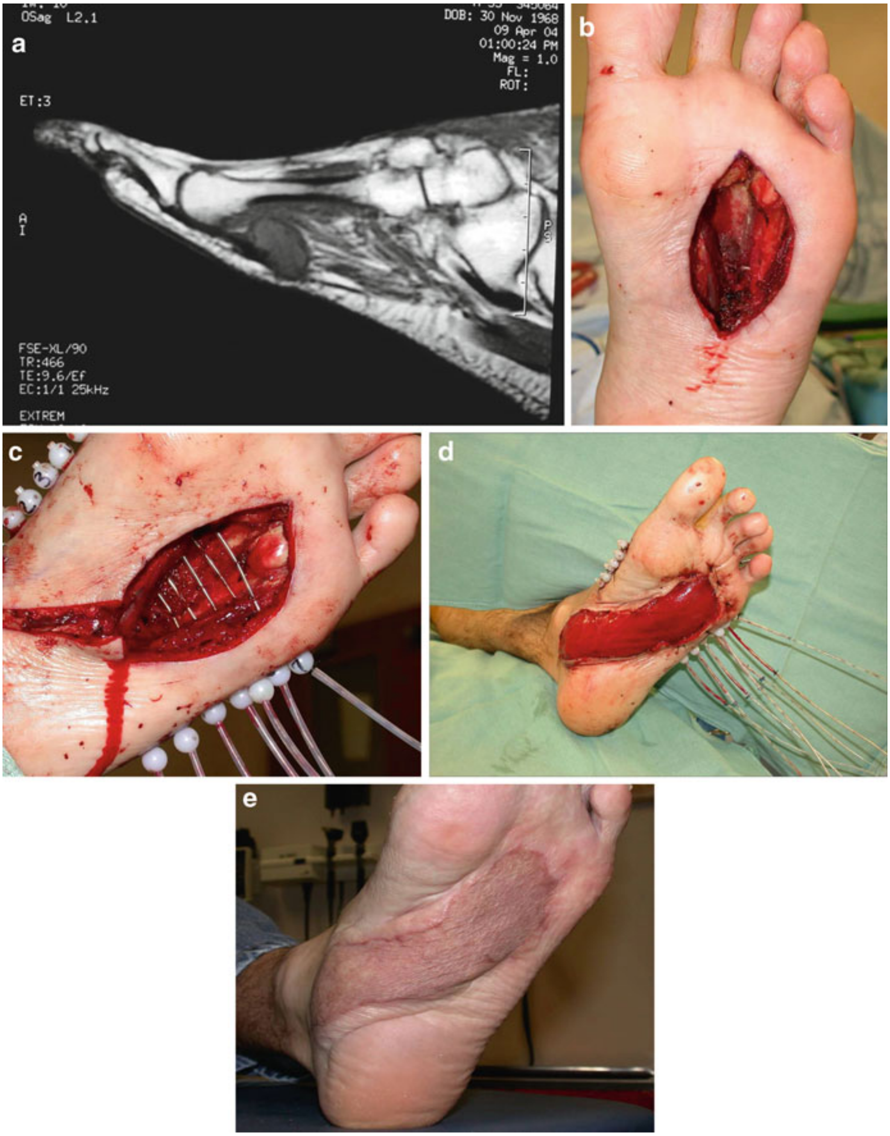

Fig. 10.5 Use of a free gracilis muscle flap for reconstruction of a plantar foot defect after tumor resection and brachytherapy catheter placement. (**a**) A recurrent sarcoma in the plantar foot. (**b**) The composite defect after excision. (**c**) Brachytherapy catheters in place. (**d**) Placement of a free gracilis muscle flap to close the wound and cover the catheters. (**e**) The healed flap several weeks after surgery.

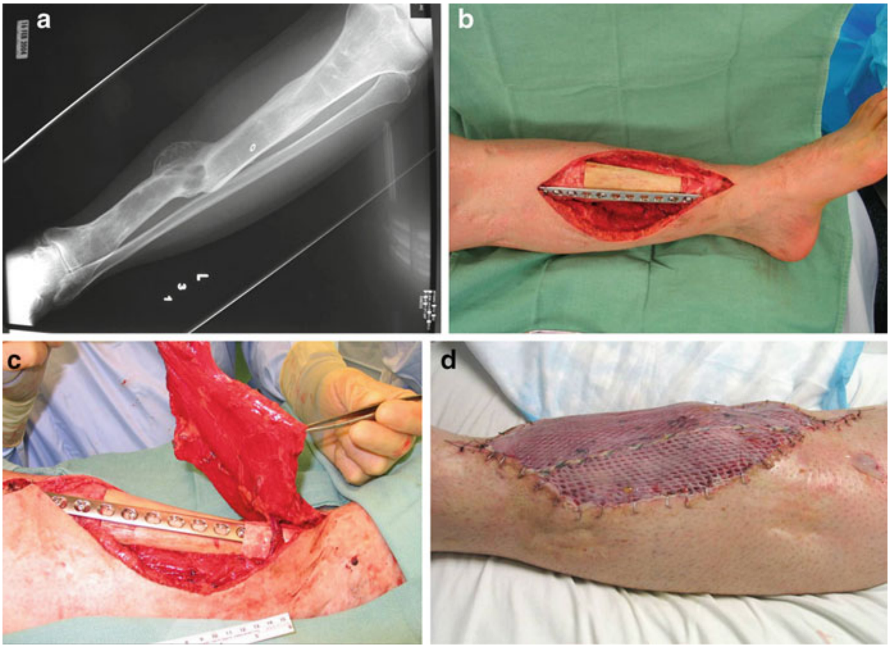

Fig. 10.6 Coverage with a free rectus abdominis muscle flap after segmental tibia resection and reconstruction for adamantinoma. (**a**) A recurrent adamantinoma in the tibia. (**b**) Tibial reconstruction with an interpositional allograft. (**c**) Use of a free rectus abdominis flap for coverage. (**d**) Early postoperative result. A skin graft has been used for closure.

the advantage of allowing primary closure of the recipient site (in most cases), but a skin graft may be required to close the donor site.

To save time, flap harvest can sometimes be performed concurrently with the resection. This timing is not always possible for a variety of reasons. First, the extent of the defect is often difficult to determine accurately before surgery. Second, the plastic surgery team may not have access to the donor site until the specimen is removed. Finally, positioning of the patient sometimes precludes access to the donor site during the resection.

When free-tissue transfers are utilized on the lower extremity, the ambulatory status of the patient will be restricted compared to that after standard prosthetic placement without flap coverage. During the patient's hospitalization, this restriction is necessary to allow initial healing of the flap and/or graft. Later, restricted ambulation and compression are used to encourage softening and atrophy of the flap, gradually increasing the time the leg is allowed in the dependent position. This regimen usually lasts 6–8 weeks after the patient is discharged, with eventual return to unlimited dependent positioning of the lower extremity.

Specialized operating room equipment and instruments and postoperative monitoring are important to achieve successful outcomes with microsurgical free-tissue transfers, and these capabilities should be in place before such reconstructions are attempted.

Regardless of the type of flap utilized, free-tissue transfers offer the ultimate in choice of donor tissue and variability of insetting options. In certain circumstances, they are the only alternative to amputation. The trade-offs are increased operative time, greater surgical complexity, potential donor-site morbidity, and prolonged rehabilitation. The increased effort on the surgeon's part and the greater need for forbearance on the patient's part are relatively small prices to pay if major complications, such as wound dehiscence and infection of the implant, are avoided.

Fillet Flap

A fillet flap is a flap taken from a portion of a limb that is being amputated. The fillet flap offers the desirable combination of a large amount of donor tissue and, usually, large-caliber vessels for vascular anastomosis (if the flap is used as a free flap). It is an excellent choice for radical amputations at the hip and shoulder girdles when the typical flaps for primary closure have been compromised by tumor, radiation, and previous surgery. In many of these situations, growth of a large tumor in the proximal portion of the extremity will have resulted in invasion of the major neurological and vascular structures, thereby rendering the limb unsalvageable. The fillet flap spares the patient the pain and morbidity of using an additional donor site. It utilizes normal tissue from the distal limb that would otherwise be lost.

Care must be exercised in determining whether a patient is a satisfactory candidate for a fillet flap. The main relative contraindication is acute or chronic lymphedema in the extremity, which can make harvest and manipulation of the soft tissues problematic.

In most cases, the fillet flap is employed as a free-tissue transfer. Pedicled fillet flaps are not often utilized because the proximal vessels are usually compromised by the tumor or by the resection. The exceptions may be where short segments of soft tissue are required (not true axial pattern flaps) or, in the hand, where the defect size is usually smaller and can be covered by one or more filleted digits.

Free-tissue transfer of fillet flaps routinely yields large amounts of tissue for reconstruction, which may be a critical advantage for massive wounds of the pelvis or chest wall. Both muscles and skin are often available, obviating the need for skin grafts (though if required, they can sometimes be harvested from another part of the amputated limb). Adequate donor vessels can usually be located because of the exposure of major vessels at the amputation site.

When amputation is deemed a possibility or is planned as part of tumor resection, the possibility of using the involved extremity to obtain a fillet flap for soft tissue coverage should always be planned in advance. The harvest of the flap must be carefully coordinated with the surgeons who perform the resection of the main tumor. These operations are often massive undertakings with large volumes of blood loss. Time is a crucial factor for success. Minimizing ischemic time for the flap and overall operative time for the patient are essential goals for the surgical team.

Key Practice Points

- After tumor resection and bony reconstruction, operative sites can benefit from closure using well-vascularized muscle or skin flaps, especially in vulnerable areas such as the proximal tibia.
- The gastrocnemius muscle flap is an excellent choice for coverage of most proximal tibial and knee reconstructions. Another pedicled flap that can be used in the leg is the soleus for central tibial defects. Both flaps can also be used together.
- For shoulder reconstruction, the latissimus dorsi or pectoralis major muscles can be used as pedicled flaps.
- The radial forearm fasciocutaneous flap can be used for reconstruction of the elbow.
- Use of free flaps may be necessary to achieve successful soft tissue reconstruction but add significant complexity to the overall operation.
- With careful planning and coordination, a fillet flap can be harvested from an unsalvageable limb and used for reconstruction.
- Close cooperation between the orthopedic and plastic surgery teams can reduce operative time and possibly patient morbidity.

Suggested Readings

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