

# 14

## Quadriceps Muscle Group Excision

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### OVERVIEW

The quadriceps muscle group is the most common site for extremity soft-tissue sarcomas. The most common sarcomas at this site are liposarcomas, malignant fibrohistiocyomas, and leiomyosarcomas. Although tumors of the anterior thigh can be extremely large prior to diagnosis, approximately 95% of these lesions may be resected. Today, resections of the anterior thigh compartment are extremely safe and reliable, and the reconstructions produce good functional results.

The quadriceps group consists of four muscles, only a portion of which may be required to be resected. When resection of the entire quadriceps muscle group is required, the defect may be reconstructed by centralization of the biceps femoris and sartorius muscles. Careful preoperative evaluation of the femoral triangle, inguinal ligament, groin, superficial femoral artery, and underlying femur is essential to surgery.

There are several treatment strategies for high-grade soft-tissue sarcomas. We prefer induction chemotherapy followed by resection. Postoperative radiation therapy is utilized only if there is less than 90% tumor necrosis or a close surgical margin. The most common indications for amputation (i.e. modified hemipelvectomy) are large tumors with extracompartmental extension into the adductor and hamstring musculature; tumors with intrapelvic extension through the femoral triangle and inguinal ligament; large fungating tumors; and massive contamination, with or without infection.

## INTRODUCTION

The quadriceps muscle group (anterior thigh musculature) is the most common anatomic site of extremity soft-tissue sarcomas (Figure 14.1). Approximately 60% of all extremity soft-tissue sarcomas arise within one of the muscles of this group. Most of our surgical experience with extremity soft-tissue sarcomas over the past several decades has been obtained in treating tumors of the anterior thigh.

Pack *et al.*, in their seven-volume textbook on the treatment of cancer, described muscle group resections for soft-tissue sarcomas in lieu of amputations.<sup>1</sup> They coined the term “muscle group” resection. Enneking *et al.*,<sup>2</sup> explained the biological and anatomic basis and growth patterns of soft-tissue sarcomas of the extremities in the 1970s. The concepts elucidated by Enneking would ultimately permit muscle group resections. Enneking emphasized that most sarcomas of the extremities arise within a muscle or group of muscles, which he termed a “compartment” (similar to muscle group). He noted that sarcomas tend to grow centrifugally, i.e. they expand (or “balloon”) within the fascial borders of their specific compartment. He emphasized that sarcomas rarely will penetrate a transverse fascial border. They will, however, extend proximally and distally within a muscle group, making it necessary surgically to remove the entire compartment to avoid a local recurrence. Enneking differentiated this growth pattern from that of carcinomas, which invade adjacent structures and are not confined by fascial or anatomic borders.

During the 1970s and 1980s Enneking developed the principles of surgical resection and established a surgical staging system and classification that is based on these biological principles. He emphasized that low-grade sarcomas can be resected safely by removing only a portion of a muscle group, as long as there is normal muscle in all directions. Surgery alone for low-grade sarcomas following these principles showed less than 10% local recurrence rate. He noted that when a high-grade soft-tissue sarcoma is treated by resection alone (as long as the entire muscle group is resected) the results were equivalent to those of amputation, i.e. a local recurrence rate of 5–10%). He concluded that a true muscle group resection from insertion to origin was equivalent biologically to an amputation one joint above the lesion.

The tendency of soft-tissue sarcomas to remain within a compartment protected by fascial borders is the biological basis that permits safe muscle group resections. Over the following decades the tendency has been to perform less than a muscle group resection when combined with adjuvant therapy and/or radiation therapy and chemotherapy. Today, less surgery is



**Figure 14.1** Clinical appearance of a typical quadriceps mass (arrows). Most tumors of the quadriceps can become quite large. They may involve one or multiple muscles of the quadriceps mechanism.

required than a true muscle group resection for select sarcomas.

This chapter discusses the unique anatomic aspects of the quadriceps muscles, describes the important staging studies for soft-tissue sarcomas that arise at this site, and presents a surgical technique for partial or complete reconstruction of the quadriceps muscle group.

## ANATOMIC CONSIDERATIONS

The thigh consists of three muscle groups: the quadriceps (anterior thigh), the adductor muscles (medial thigh); and the hamstring muscle (posterior thigh). The quadriceps muscle group consists of the vastus medialis, vastus lateralis, rectus femoris, and vastus intermedius muscles. Soft-tissue sarcomas may arise in any of the four muscles (i.e. intramuscularly) or between them (i.e. extramuscularly); however, they are intracompartmental (i.e. arising within the quadriceps muscle group). The vastus medialis, lateralis, and intermedius arise from the proximal femur and intermuscular septum and insert onto the patella. Only the rectus femoris arises from the pelvis and also inserts onto the patella.

It is important to note that only the vastus intermedius muscle arises from the surface of the femur and the linea aspera and covers the entire femoral shaft. Thus, the vastus intermedius protects the underlying femur from direct tumor extension by tumors of the other quadriceps muscles. Tumors arising within the vastus intermedius lie on the periosteum of the femur, or extend to the linea aspera. Tumors arising within other portions of the quadriceps generally remain localized to their respective muscle belly and only rarely cross into a second muscle. This anatomically permits partial muscle group resection for many quadriceps sarcomas.

The medial and lateral intermuscular septum of the thigh separates the anterior thigh muscles from the posterior compartment as well as the medial compartment. The medial intermuscular septum, however, "runs out" proximally; quadriceps tumors may therefore extend into the posterior and medial compartments and make a limb-sparing resection difficult. Similarly, tumors of the posterior thigh and/or the adductor group may extend into the quadriceps group, making resections more difficult.

The anatomic structures that must be evaluated prior to surgery are the superficial femoral artery, the femoral triangle, and the adductor hiatus.

The femoral triangle is the key to resection of the quadriceps muscle group. It is formed by the adductor longus medially, the sartorius muscle laterally, and the inguinal ligament proximally. The pectineus muscle forms the floor of the triangle. A thick fascia covers the roof. The superficial femoral artery and vein pass from below the inguinal ligament through the femoral triangle and into the sartorial canal at the apex. The femoral nerve enters the canal laterally and quickly divides to innervate the quadriceps muscles. The superficial femoral artery and vein pass along the medial wall of the sartorial canal throughout the length of the thigh and are separated from the anterior group (vastus medialis) by a thick fascia, which often permits a safe

resection. The vastus medialis fascia forms a good border for quadriceps resections.

## STAGING STUDIES

### CAT and MRI

Computerized axial tomography (CAT) and magnetic resonance imaging (MRI) are important to determine the extent of soft-tissue sarcomas of the anterior thigh, and which quadriceps muscles are involved (Figure 14.2). Tumors may remain within one muscle or involve several muscles. It is important to identify the relationship of the involved and the underlying femur. If the vastus intermedius is involved by tumor, the adjacent periosteum is always involved as well.

### Bone Scan

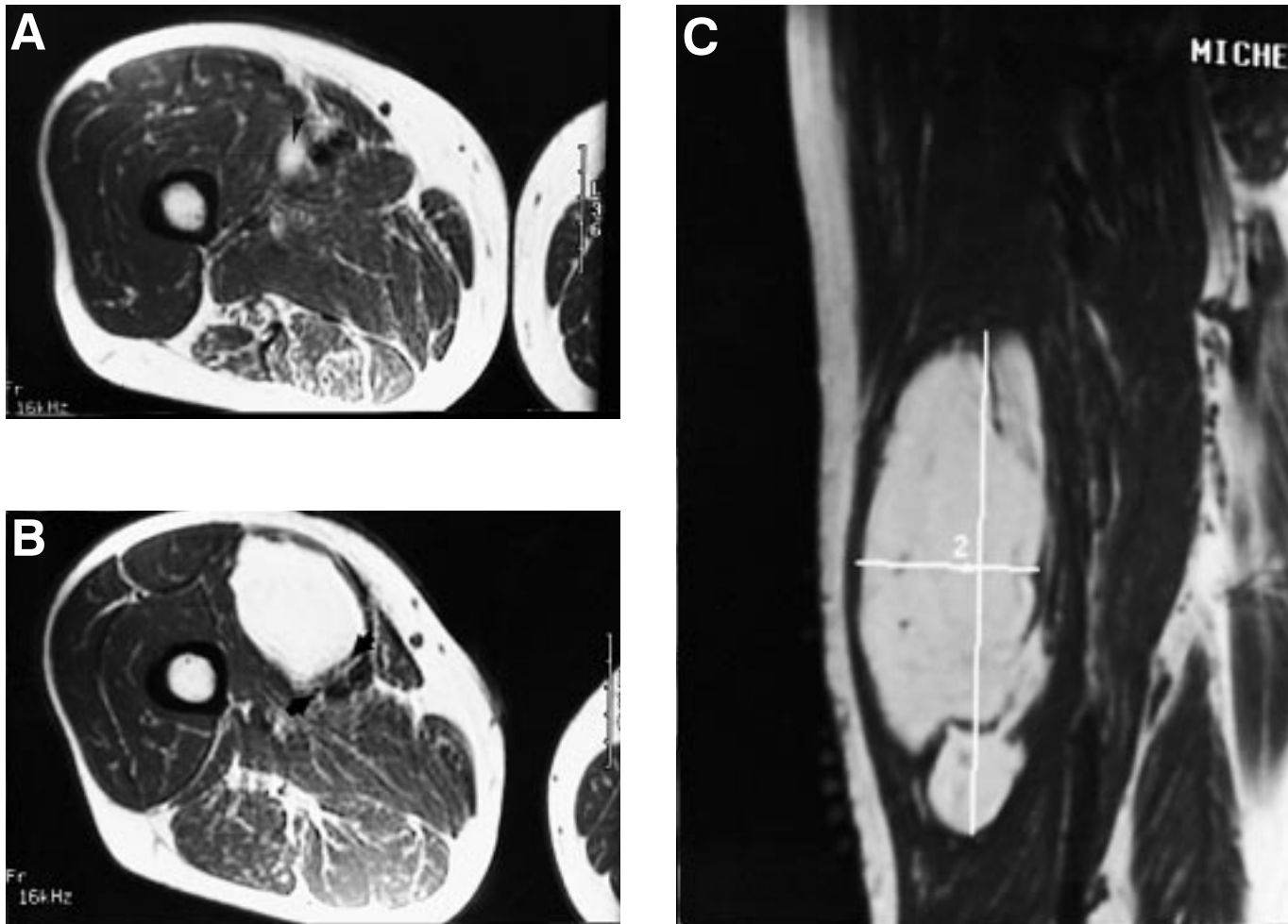
A three-phase bone scan is useful to determine the proximity of the tumor to the periosteum. Absence of periosteal uptake indicates a reactive border or a pseudocapsule. This does not make quadriceps tumors unresectable, but it does indicate that the underlying periosteum must be removed during the surgical procedure. Tumors of the vastus intermedius routinely show increased uptake of the underlying femur. Rarely does tumor extend directly into the bone.

### Biplane Angiography

Large tumors of the quadriceps muscle often displace the superficial femoral artery and the profundus femoris artery and vein (Figure 14.3). It is important to determine the anatomic relationship of these vessels to the tumor prior to resection. Large tumors of the proximal thigh may require ligation of the profundus femoris artery and vein; therefore it is important to know prior to surgery whether the superficial artery is patent. This is particularly true in the older patient, in whom the SFA may be occluded because of disease. Superficial femoral artery displacement does not usually indicate direct tumor extension, but if the margin is close, a femoral artery graft can be utilized.

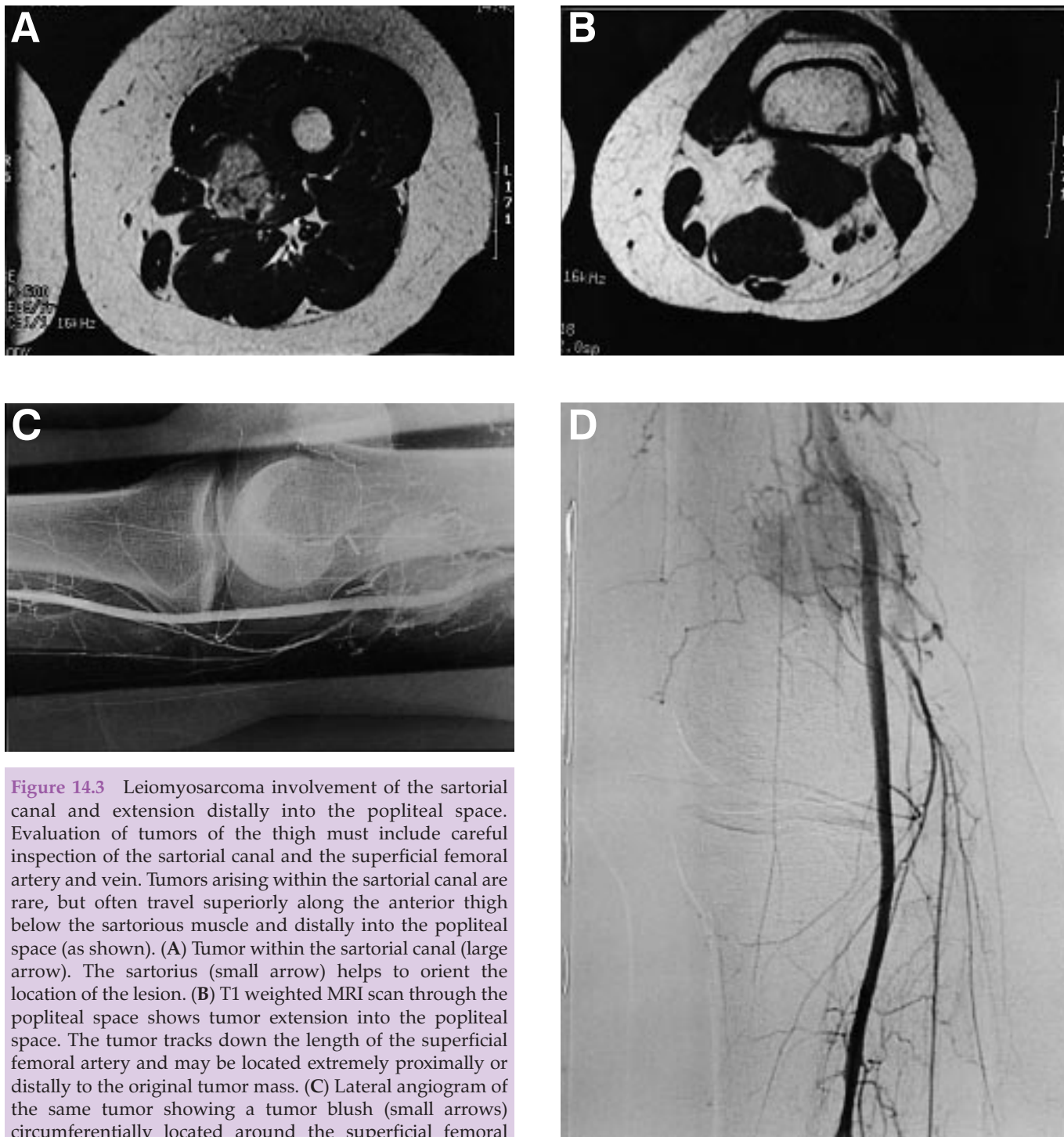
## INDICATIONS AND CONTRAINDICATIONS TO LIMB-SPARING RESECTION

Almost all low-grade soft-tissue sarcomas of the anterior thigh may be safely resected by a partial muscle group resection. The large majority of high-grade soft-tissue sarcomas can be resected by partial or total compartmental removal. The contraindications to limb-sparing resection are as follows:



**Figure 14.2** MRI evaluation of a quadriceps mass. (A) Axial T1 weighted image. Note the small tumor of the inferior aspect of the vastus medialis adjacent to the superficial femoral artery and vein (small arrow). (B) Axial T1 weighted image of the same patient shows large tumor involvement of the vastus medialis muscle but it is separated from the superficial femoral artery and vein (sartorial canal) by a thick fascial border of the vastus medialis (solid arrows) This fascia usually provides a safe resection margin. (C) Sagittal image of the same tumor (low to intermediate grade liposarcoma) showing almost a separate tumor with a small connection to the primary mass. Liposarcomas characteristically may have multiple lesions within the same muscle belly.

1. *Groin involvement.* Tumors arising or involving the groin and femoral triangle often cannot be reliably resected and may require amputation.
2. *Extracompartmental extension.* In general, a single muscle group permits a viable extremity. If two muscle groups have to be removed, the extremity is probably not salvageable. Large tumors of the anterior thigh may involve the adductor group as well as the posterior muscle group by passing through the linea aspera or the intermuscular septum. In this situation amputation is necessary.
3. *Intrapelvic extension.* On rare occasions, large tumors of the proximal thigh and groin extend below the inguinal ligament into the retroperitoneal space, necessitating amputation.
4. *Superficial femoral artery or common femoral artery involvement.* Most tumors of the quadriceps muscle will displace, but do not invade superficial femoral artery or common femoral artery. If there is a minimal margin, resection of the artery with a vascular graft can avoid an amputation. Femoral nerve sacrifice is not a contraindication to resection, because hamstring transfers can restore stability of the lower extremity if the entire muscle group is resected.
5. *Femur involvement.* Large tumors often involve the underlying femur and multiple compartments. This is particularly true of tumors of the vastus intermedius. This combination usually requires an amputation, especially if there is poor response to induction therapy (radiation or chemotherapy).



**Figure 14.3** Leiomysarcoma involvement of the sartorial canal and extension distally into the popliteal space. Evaluation of tumors of the thigh must include careful inspection of the sartorial canal and the superficial femoral artery and vein. Tumors arising within the sartorial canal are rare, but often travel superiorly along the anterior thigh below the sartorius muscle and distally into the popliteal space (as shown). (A) Tumor within the sartorial canal (large arrow). The sartorius (small arrow) helps to orient the location of the lesion. (B) T1 weighted MRI scan through the popliteal space shows tumor extension into the popliteal space. The tumor tracks down the length of the superficial femoral artery and may be located extremely proximally or distally to the original tumor mass. (C) Lateral angiogram of the same tumor showing a tumor blush (small arrows) circumferentially located around the superficial femoral artery. (D) Subtraction angiogram showing tumor blush at the level of the popliteal space and the sartorial canal. This patient was treated by wide excision of the vastus medialis and the sartorial canal along with the superficial femoral artery and vein, and was reconstructed with a long Gore-Tex® graft.

6. *Palliation.* Recurrent tumors of the quadriceps, infection, extensive tumor hemorrhage, or extensive contamination from previous surgical procedures may require an amputation.

### BIOPSY

The biopsy site should be in line with the potential incision for resection. This incision extends proximally from lateral to the femoral triangle, parallels the sartorial canal, and curves medially over to the adductor hiatus. The biopsy should be over the most prominent portion of the tumor. We recommend core needle biopsy. Multiple samples can be collected from the same puncture site. The femoral triangle, sartorial canal, hip joint, patella, and popliteal space should be avoided to prevent contamination.

### SURGICAL GUIDELINES

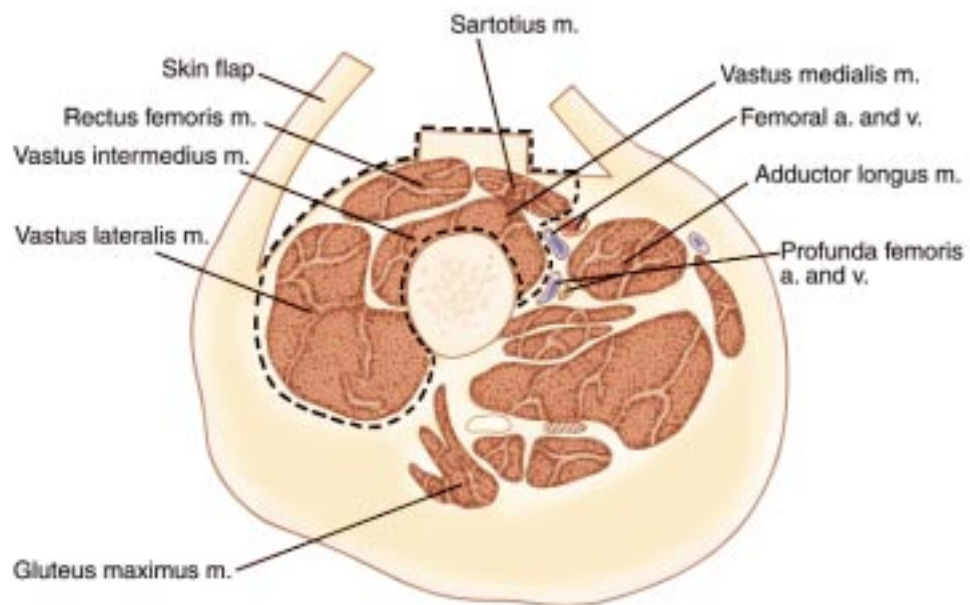
The guidelines and technique of complete or partial anterior thigh (quadriceps muscle group) resection are:

1. The superficial artery and vein are initially explored throughout the length of the sartorial canal and must be free of tumor.

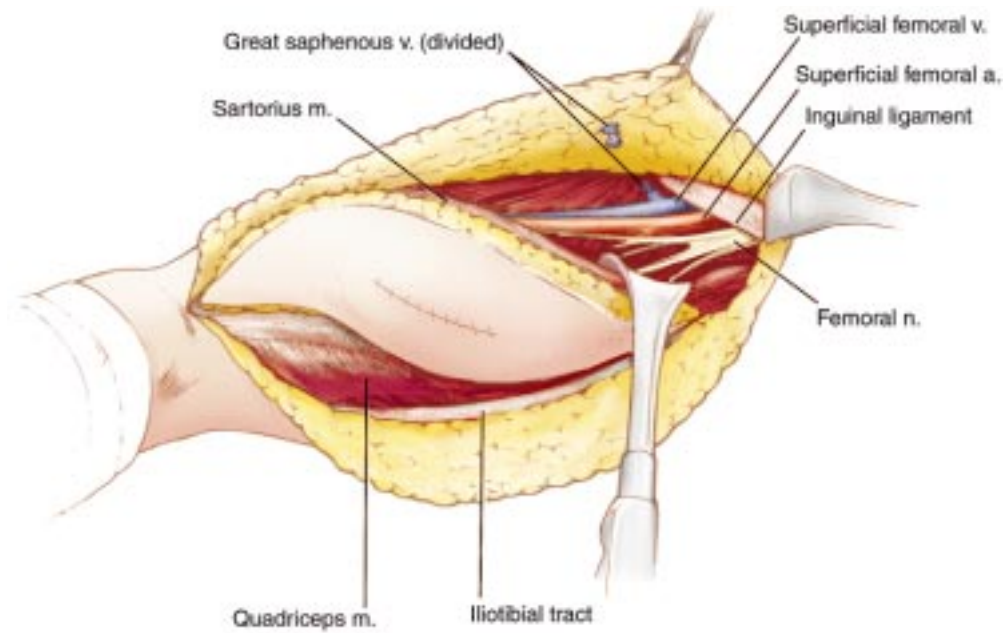
2. A long midline incision is utilized with large medial and lateral flaps in order to expose the planes of resection (the intermuscular septum).
3. The entire quadriceps muscle group or a portion thereof is resected. If the underlying femur is the closest border, the periosteum can be removed and the underlying bone exposed by utilizing a high-speed burr (Midas). Several millimeters of the outer cortex can be removed; however, the outer cortex itself should not be removed en-bloc. This may not be necessary following induction chemotherapy and/or postoperative radiation therapy.
4. The sartorius muscle is usually preserved and utilized to cover the femoral vessels following resection.
5. If no quadriceps muscles remain, a primary transfer of the long head of the biceps, as well as a transfer of the sartorius and gracilis to the patella, should be performed to restore the lost quadriceps power and close the operative dead space.
6. A 28-gauge chest tube is utilized to drain the surgical space and avoid postoperative hematomas.



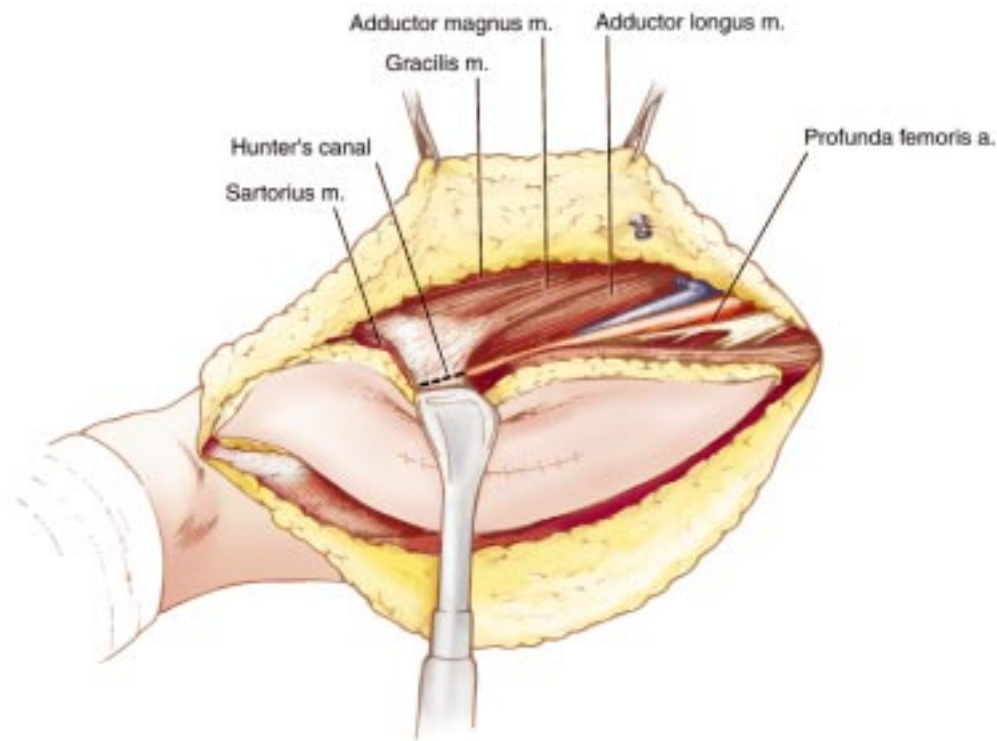
**Figure 14.4** Incision. The incision extends longitudinally from the anterior inferior iliac spine to the patella. It should be elliptical in configuration and widely encompass the biopsy site. If physical examination or tomography shows that the tumor encroaches on the patella, this bone and its tendon should also be excised. If this clinical situation arises, the incision should be continued over the knee to the tibial tubercle.



**Figure 14.5** Cross-sectional anatomy.

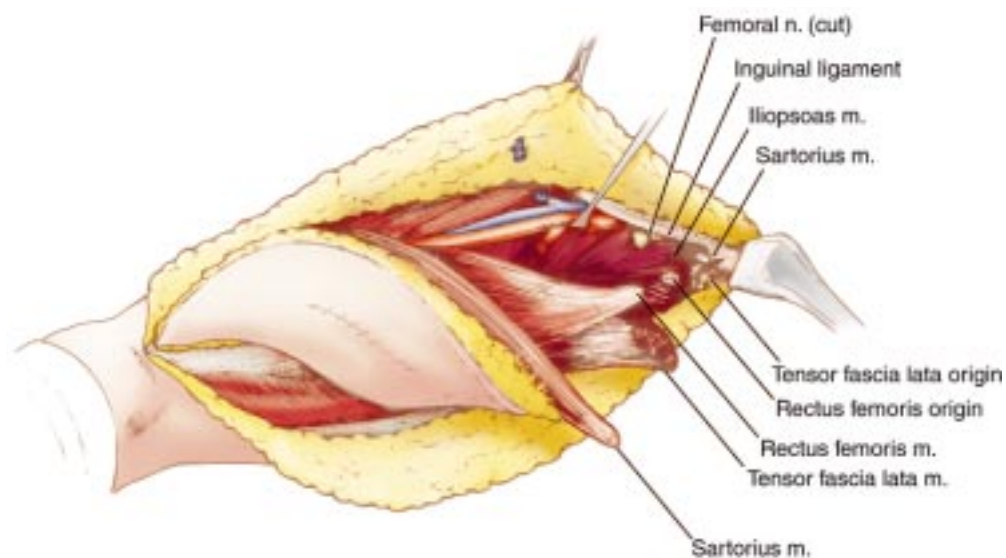


**Figure 14.6** Skin flaps. Flaps composed of skin and subcutaneous tissue are made just superficial to the fascia lata. They extend to the abductor muscle group medially and to the greater trochanter and flexor muscles laterally. The saphenous vein is divided as it enters the fossa ovalis. The inguinal ligament and the femoral triangle are uncovered, exposing the common femoral artery and vein and the femoral nerve.

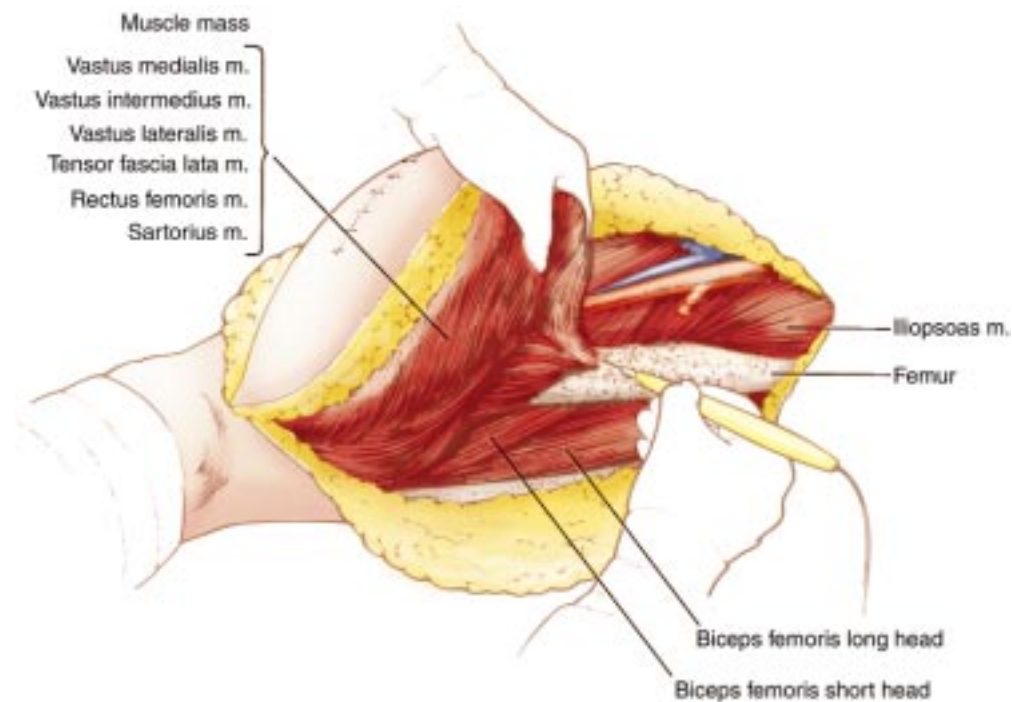


**Figure 14.7** Dissection of the superficial femoral vessels. Lateral traction is placed on the quadriceps muscle group so that muscular branches coming from the superficial femoral artery and vein into the quadriceps muscle are exposed. Working from cranial to caudal, these vessels are clamped, divided, and ligated; included are the profunda femoris artery and vein. In the area of Hunter's canal, when strong lateral traction is placed on the sartorius muscle, muscular insertions from the abductor magnus muscle coursing over the superficial femoral artery are identified. These muscle fibers should be divided as they cross the superficial femoral artery.

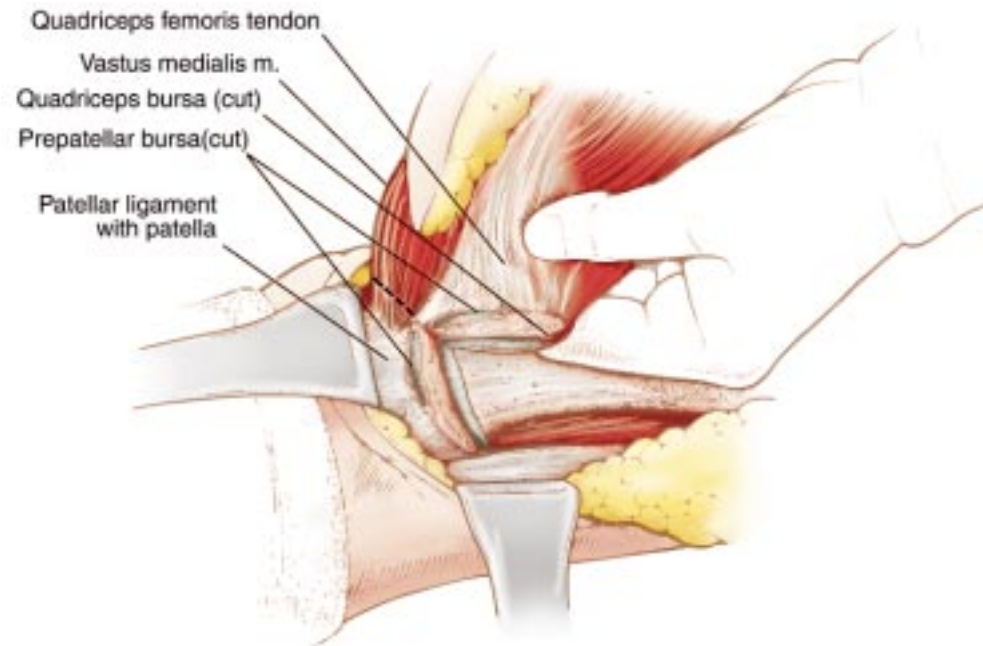




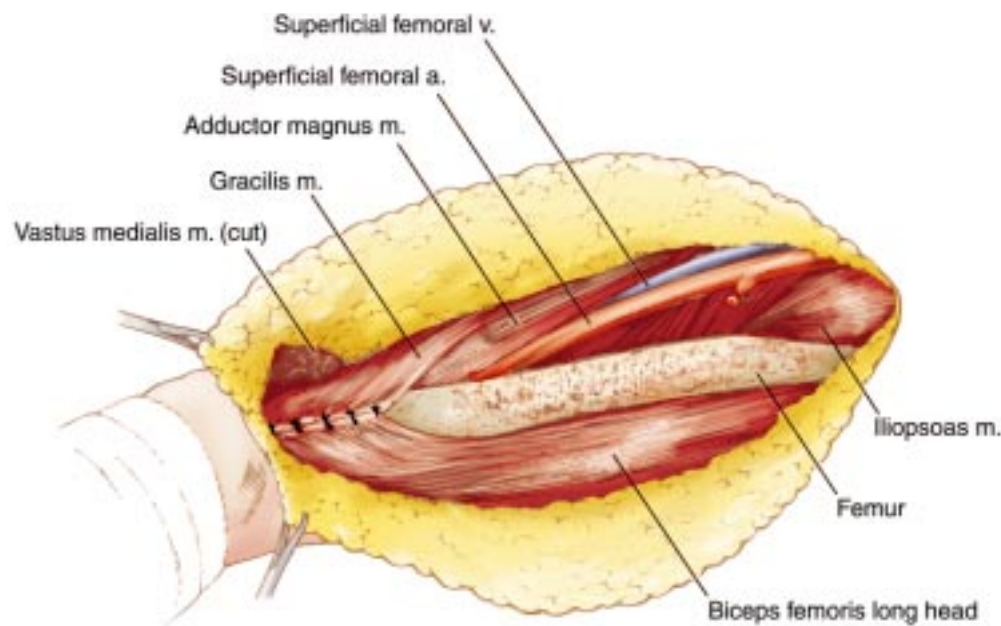
**Figure 14.8** Transection of muscle origins on the pelvis. A plane beneath the tensor fascia lata muscle and above the gluteus medius and minimus is identified. By electrocautery the tensor fascia lata muscle is released from its origin on the wing of the ilium. Then the origin of the sartorius muscle on the anterior superior iliac spine is identified and divided. The origin of the rectus femoris muscle on the anterior inferior iliac spine is likewise identified and divided through its tendinous portion.



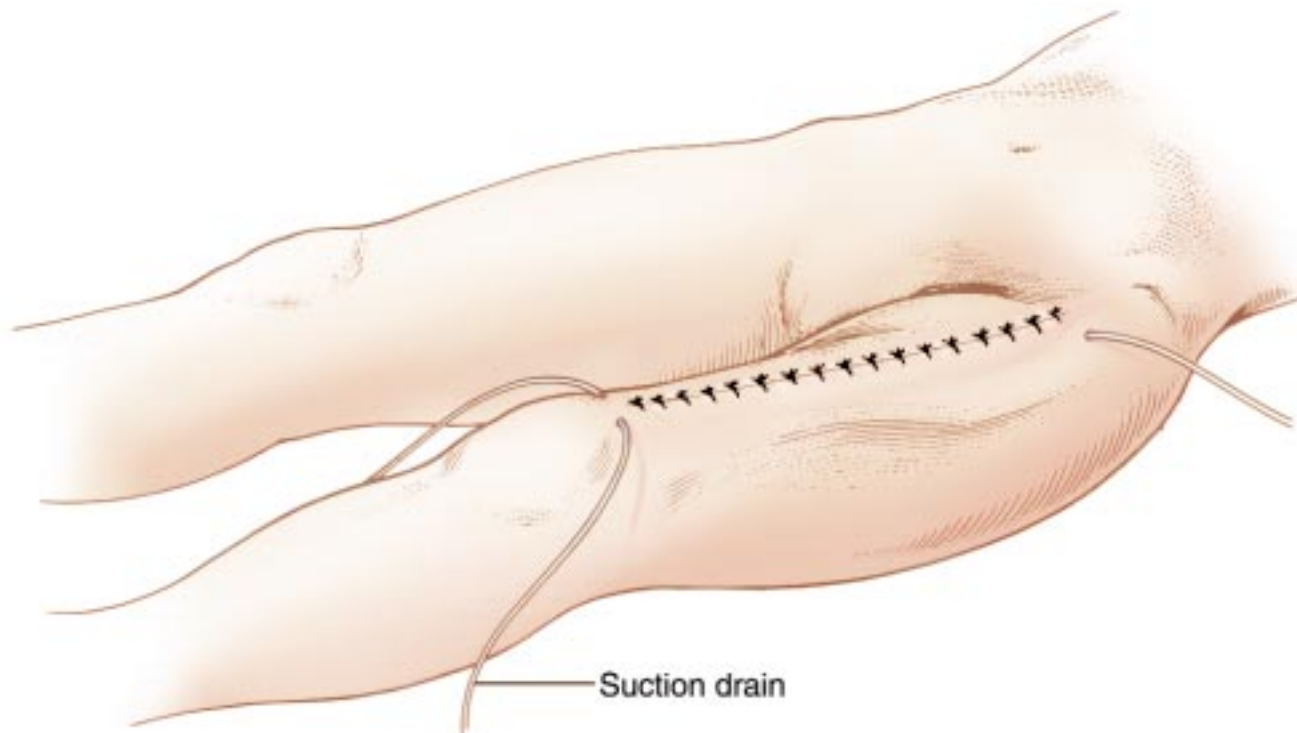
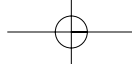
**Figure 14.9** Transection of muscle origins on the femur. Origins of the vastus lateralis, vastus intermedius, and vastus medialis on the femur are transected from bone by using electrocautery. Strong upward traction on the muscle group facilitates this dissection.



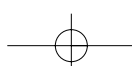
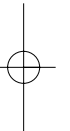
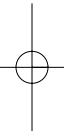
**Figure 14.10** Transection of the muscle insertions of the quadriceps muscle. Using strong upward and medial traction on the specimen, insertions of the vastus lateralis, vastus medialis, and rectus femoris into the patellar tendon are divided on the patella bone. One cannot avoid transecting both the prepatellar and quadriceps (postpatellar) bursae. The insertion of the vastus medialis into the medial collateral ligament is likewise divided, and the specimen is then free. The dissection site is copiously irrigated, and any bleeding points are secured with ligatures or electrocautery.



**Figure 14.11** Reconstruction. To facilitate rehabilitation by helping to provide stability to the knee, the gracilis muscle medially and the short head of the biceps muscle laterally are transected at their insertions on the medial and lateral collateral ligaments. This transection should be as far distal on the muscle as possible so that a tendinous portion of the muscle is retained on the muscle belly. Then, using heavy nonabsorbable sutures, these two muscles are transplanted onto the patellar tendon. The prepatellar and quadriceps bursae are closed within these sutures. The muscles are approximately in the midline so that they cover the distal one-third of the femur.



**Figure 14.12** Closure. Suction catheters are placed beneath the skin flaps and the subcutaneous tissue is approximated with interrupted absorbable sutures. The skin is closed. No immobilization using plaster is required and the incision is merely covered with povidone iodine ointment and a loose dry sterile dressing. The patient may begin ambulation when the suction catheters have been removed and edema of the leg has resolved. Because lymphatics along the superficial femoral artery and within the buttock remain intact, prolonged swelling is not usually a problem. Also, because muscles have been removed from origin to insertion, serous drainage from transected muscle bundles does not occur in large amounts. The patient is ambulated initially with crutches and a touchdown gait.



## DISCUSSION

Today, preoperative induction chemotherapy and/or radiation therapy permits a safe limb-sparing resection of approximately 95% of all soft-tissue sarcomas of the anterior thigh. The authors prefer preoperative induction chemotherapy for most high-grade soft-tissue sarcomas of the anterior thigh. We utilize postoperative radiation therapy only if there is less than 90% tumor necrosis or for a close surgical margin.

The major anatomic considerations in treating tumors of the anterior thigh are the femoral vessels and the relationship of the tumor to the underlying femur. The superficial femoral artery must be evaluated by biplane angiography and, if necessary, resection and a vascular graft are performed. It is important to note that the vastus intermedius protects the underlying femur from most tumors of the other anterior muscles. Arising from the entire diaphyseal surface of the femur and from the linea aspera, the vastus intermedius is interposed between the femoral shaft and the remaining quadriceps muscles. If a tumor arises within the intermedius muscle, an amputation can still be avoided by administering induction chemotherapy and/or radiation therapy, resecting the vastus intermedius, and utilizing high-speed burr to remove the outer 2–3 mm of the exposed femoral cortex. A cortical resection is never performed.

The main indications for amputation are large, fungating tumors, especially of the proximal thigh and groin; extracompartmental extension into the adductor and/or hamstring compartments; intrapelvic extension below the inguinal ligament; or a combination of the above.

In general, most patients today are treated by partial muscle group resections of the quadriceps muscles, followed by radiation therapy. Induction chemotherapy or radiation therapy is performed in several centers. If a portion of the anterior thigh musculature remains, reconstruction is not required. If the entire anterior thigh musculature is removed, reconstruction is performed by centralizing the long head of the biceps femoris and the sartorius and gracilis muscles anteriorly along the anterior aspect of the thigh and suturing into the patellar tendon. This restores functional stability of the knee. In general, the results of this transfer are good, and active knee extension is restored. If radiation therapy is required, lymphedema is usually not a problem because the lymph nodes are not routinely resected. Lymph node involvement rarely occurs with soft-tissue sarcomas.

Today, the quadriceps compartment can generally be safely resected and reconstructed. Amputation is rarely required.

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