Chapter 30 Quadriceps Resections

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BACKGROUND
- The quadriceps muscle group is the most common site for extremity soft tissue sarcomas.
- The most common sarcomas at this site are liposarcomas, malignant fibrous histiocytomas, and leiomyosarcomas.
- Although tumors of the anterior compartment of the thigh can be extremely large on first presentation, it is possible to perform limb-sparing resections in most patients. By using induction chemotherapy to shrink the lesion and postoperative adjuvant radiation therapy to eradicate possible residual microscopic disease, resections of the anterior compartment of the thigh are often safe and reliable.
- In addition, when resection necessitates en bloc removal of a considerable amount of muscle tissue, reconstruction of the extensor mechanism with the sartorius muscle, the hamstring muscles, or both produces good functional results.
- The most common indications for amputation (ie, 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 tumor contamination, with or without infection.

INDICATIONS
- 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:
  - Groin involvement. Tumors arising or involving the groin and femoral triangle often cannot be reliably resected and may require amputation.
  - Extracomartmental extension. In general, resection of a single muscle group permits a viable extremity. If two muscle groups have to be completely removed, the extremity may not be functionally 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 might be necessary.
  - Intrapelvic extension. On rare occasions, large tumors of the proximal thigh and groin extend below the inguinal ligament into the retroperitoneal space, necessitating amputation.
  - Recurrent tumors of the quadriceps, infection, extensive tumor hemorrhage, or extensive tumor contamination from previous surgical procedures may require amputation.
  - Neurovascular involvement of the tumor does not necessarily obviate limb-salvage resections. Most tumors of the quadriceps muscle will displace but not invade the superficial femoral or common femoral arteries. If the surgical margins are positive for tumor cells or extremely close, resection of the involved artery and replacement with a vascular graft often allows limb salvage.

- Femoral nerve sacrifice is also not a contraindication for limb-sparing resection; reconstruction techniques often permit knee extension and patellar stabilization, even when the entire quadriceps muscle is resected or paralyzed secondary to femoral nerve resection (Tables 1 and 2).

ANATOMY
- The thigh consists of three distinct anatomic compartments, separated by thick fascial layers: the anterior compartment (quadriceps and sartorius muscle), the medial compartment (thigh adductor muscles), and the posterior compartment (the hamstring muscles).
- The quadriceps muscle group consists of the vastus medialis, vastus lateralis, rectus femoris, and vastus intermedius muscles. The vastus medialis and lateralis arise from the proximal femur and intermuscular septum. The vastus intermedius arises from the surface of the femur and the linea aspera and covers the entire femoral shaft. The rectus femoris arises from the supra-acetabular tubercle at the superior part of the acetabulum. All four heads merge distally into the quadriceps tendon, which inserts onto the patella.
- By covering the anterior aspect of the femur, the vastus intermedius protects the underlying femur from direct tumor extension by tumors of the other components of quadriceps muscle.
- The fact that soft tissue sarcomas often remain localized to one muscle belly permits partial muscle group resection for many quadriceps sarcomas (FIG 1).
- The medial and lateral intermuscular septum of the thigh separates the anterior thigh muscles from the medial and posterior compartments, respectively. However, the medial intermuscular septum “runs out” proximally, and quadriceps tumors may therefore extend into the posterior and medial compartments and complicate and sometimes obviate a limb-sparing resection. Likewise, tumors arising from the medial and posterior compartments of the thigh may extend into the quadriceps group.
- 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 branches to innervate the quadriceps muscle components. 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.
- This fascia forms a good border for quadriceps resections.

Unique Anatomic Considerations
- An important criterion for the success of a muscle flap transfer (FIG 2A–D) is maintenance of a pattern of circulation that
is consistent in location and resistant to the effect of radiation therapy and superficial trauma (FIG 2E). The surgical manipulation of the muscle flap must not interrupt its circulation; therefore, a precise knowledge of the location and pattern of the vascular pedicles is required. The sartorius muscle is supplied by the superficial femoral artery and has a segmental vascular pattern (type IV vascular pattern according to Mathes and Nahai). Each pedicle provides circulation to a portion of the muscle, and division of more than three pedicles during the elevation of the flap may result in distal muscle necrosis. The hamstring muscles are supplied by branches of the profunda femoris artery and have proximal dominant vascular pedicles and distal minor pedicles (type II vascular pattern). Complete elevation of the muscles is possible when the dominant proximal vascular pedicles are preserved.

**IMAGING AND OTHER STAGING STUDIES**

**Computation Tomography and Magnetic Resonance Imaging**

- Magnetic resonance imaging (MRI) and computed axial tomography (CAT) are essential for determining the location and extent of the lesion and its relations to the femoral bone, respectively.
- Tumors may remain within one muscle belly or involve several components of the quadriceps muscle.
- It is important to identify the relationship between the tumor and the underlying femur. Tumors that involve the vastus medialis very often involve the adjacent peristeum 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 indicates that the underlying periosteum must be removed during the surgical procedure. Rarely does tumor extend directly into the bone.

**Angiography and Other Studies**

- Large tumors of the quadriceps muscle often displace the superficial and deep femoral vessels. It is important to determine the anatomic relations of these vessels to the tumor before resection. Large tumors of the proximal thigh may require ligation of the profundus femoris artery and vein; therefore, knowing before surgery whether the superficial artery is patent is essential. This is particularly true in the older patient, in whom the superficial femoral artery may be occluded secondary to peripheral vascular disease. Displacement of the superficial femoral artery usually does not indicate direct tumor extension; however, if the surgical margins are positive, the artery should be resected and replaced with a saphenous or artificial graft.

**Biopsy**

- The biopsy site should be in line with the planned incision for resection and must be located over the most prominent portion of the tumor. Core needle biopsy has been shown to provide reliable pathologic diagnoses and is our preferred method. Multiple samples can be collected from the same puncture site. Areas that major arteries and veins traverse should be avoided so that the vessels are not penetrated, risking cell contamination.
FIG 2 • A. Muscle transfers for type A resection (vastus lateralis with or without vastus intermedius). The long head of the biceps femoris is transferred anteriorly and sutured to the patella, the quadriceps tendon, and the rectus femoris muscle. B. Muscle transfers for type B resection (vastus medialis with or without vastus intermedius). The sartorius muscle is transferred anteriorly but not detached from its distal insertion and is sutured to the patellar tendon, patella, quadriceps tendon, and rectus femoris muscle. C. Muscle transfers for type C resection (rectus femoris and vastus intermedius). The sartorius muscle is mobilized anteriorly and sutured to the patella and the remains of the quadriceps tendon. D. Muscle transfers for type D resection (subtotal resection). The biceps femoris laterally and the sartorius and semitendinosus medially are transferred anteriorly, tenodesed to each other, and sutured to the patella. E. Vascular anatomy of muscles. There are five patterns of vascular supply to muscles, based on the distribution of major and minor vascular pedicles. The sartorius muscle has a type II vascular pattern and the hamstring muscles have a type IV vascular pattern (represented by the gracilis muscle in the schematic).
The patient is placed in the supine position with a bolster underneath the ipsilateral buttock. If the tumor is close to or involves the femoral artery, the contralateral leg should also be draped for saphenous vein graft harvesting, in case the femoral artery needs to be resected (TECH FIG 1).

**POSITION**

- The patient is placed in the supine position with a bolster underneath the ipsilateral buttock. If the tumor is close to or involves the femoral artery, the contralateral leg should also be draped for saphenous vein graft harvesting, in case the femoral artery needs to be resected (TECH FIG 1).

**LIMITED RESECTIONS OF THE QUADRICEPS MUSCLE**

- Most tumors of the anterior compartment of the thigh are confined to one part of the quadriceps muscle and can be safely resected with negative margins without the need to sacrifice a considerable amount of muscle tissue.
- A longitudinal skin incision just above the tumor mass is made, encompassing the biopsy site. The tumor mass should be resected en bloc with 1 cm of surrounding healthy tissue.
- For tumors that involve the vastus medialis, vastus lateralis, or rectus femoris, the superficial margins are the skin and subcutaneous tissues and the deep margins may include part of the vastus intermedius. The superficial margins of tumors that involve the vastus intermedius may include part of one of the vasti or rectus femoris. If the deep surface of the tumor is close to the bone, the periosteum should be peeled off and resected and the superficial cortex removed with a high-speed burr (Midas).

**PARTIAL OR COMPLETE QUADRICEPS RESECTION**

- A long midline incision is made extending longitudinally from the anterior inferior iliac spine to the patella. It should be elliptical and should widely encompass the biopsy site (TECH FIG 2A).
- Flaps composed of skin and subcutaneous tissue are made just superficial to the fascia lata. They extend to the adductor 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 (TECH FIG 2B).
- 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 the canal of Hunter, while strong lateral traction is placed on the sartorius muscle, muscular insertions from the adductor magnus muscle coursing over the superficial femoral artery are identified. These muscular branches should be divided as they cross the superficial femoral artery (TECH FIG 2C,D).
- 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 (TECH FIG 2E).
- The origins of the vastus lateralis, vastus intermedius, and vastus medialis on the femur are transected from the bone using electrocautery. Strong upward traction on the muscle group facilitates this dissection (TECH FIG 2F,G).
- Using strong upward and medial traction on the specimen, the insertions of the vastus lateralis, vastus medialis, and rectus femoris into the patellar tendon are divided on the patella (TECH FIG 2H).
- 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.
The incision extends longitudinally from the anterior inferior iliac spine to the patella. It should be elliptical and should 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.

Cross-sectional anatomy.

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.

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 the canal of Hunter, 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.

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.

Resection includes the vastus lateralis and part of the vastus intermedius and rectus femoris. (continued)
H. 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.

I. Transection of the muscle insertions of the quadriceps muscle. Using strong upward and medial traction on the specimen, the insertions of the vastus lateralis, vastus medialis, and rectus femoris into the patellar tendon are divided on the patella bone. 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.

J. 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 as possible so that a tendinous portion of the muscle is retained. 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 approximated in the midline to cover the distal third of the femur.

K. After completion of the resection, the lateral aspect of the femur is exposed. Suction catheters are placed beneath the skin flaps and the subcutaneous tissue is approximated. The skin is closed and the incision is 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 the lymphatics along the superficial femoral artery and within the buttock remain intact, prolonged swelling is not usually a problem, serous drainage from transected muscle bundles does not occur in large amounts. The patient is ambulated initially with crutches and a touch-down gait.
If the tumor is close to the underlying femoral bone (TECH FIG 2I), the periosteum can be removed and the underlying bone exposed using 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.

**Suction catheters are placed beneath the skin flaps and the subcutaneous tissue is approximated with interrupted absorbable sutures. We recommend using 28-gauge chest tubes to drain the surgical space (TECH FIG 2K).**

**SOFT TISSUE RECONSTRUCTION OF RESIDUAL LARGE DEFECTS**

- If a significant amount of quadriceps muscle is resected or if the femoral nerve must be sacrificed, we routinely reconstruct the extensor mechanism to restore strength and balance patellar tracking. The long head of the biceps femoris muscle is used to reconstruct the lateral aspect of the quadriceps muscle (TECH FIG 3), and the sartorius muscle, the semitendinosus muscle, or both are used to reconstruct the medial aspect of the quadriceps muscle.

- Another technique that can be used to functionally reconstruct large defects (which is not within the scope of this textbook) is latissimus dorsi microvascular transplantation. We believe it should be used whenever muscle transfers cannot be performed.

**BICEPS FEMORIS TRANSFER FOR FUNCTIONAL RECONSTRUCTION OF LARGE LATERAL SOFT TISSUE DEFECTS**

- After completion of the resection, the long head of the biceps is transected from its insertion on the head of the fibula. This transection should be as far distal as possible to retain a tendinous portion of the muscle. The muscle is transferred anteriorly to the midline so that it will have an almost direct line of pull. Only a few deep perforating branches need to be ligated during this procedure. Due to the type II vascular pattern of the hamstring muscles, ligation of distal branches does not jeopardize its vitality. Then, using heavy, nonabsorbable sutures, the muscle is transplanted onto the patella and the remains of the quadriceps.

**SARTORIUS AND SEMITENDINOSUS MUSCLE TRANSFER FOR FUNCTIONAL RECONSTRUCTION OF CENTRAL AND MEDIAL SOFT TISSUE DEFECTS**

- The sartorius, the semitendinosus, or both can be used to functionally reconstruct large medial defects. Large central defects are reconstructed with the sartorius muscle.

**Sartorius Muscle Transfer**

- After completion of the resection, the sartorius muscle is released, but not transected, from its distal insertion on the medial aspect of the proximal tibia. The aim is to transfer the muscle anteriorly to the midline to achieve a straight line of pull between its origin on the anterior superior iliac spine and the patella. After ligating only two or three distal vascular branches, the sartorius can easily be transferred toward the midline and sutured to the patellar tendon, the patella, and the remains of the quadriceps tendon. Since the sartorius muscle has a type IV vascular pattern, care should be taken not to ligate more than three vascular branches to prevent distal flap necrosis (Table 3).
POSTOPERATIVE CARE AND REHABILITATION

- Continuous suction is required for 3 to 5 days and perioperative intravenous antibiotics are continued until the drainage tubes are removed. If muscle transfer reconstruction was performed, a knee extension brace is initially used and an intensive physical therapy program for muscle strengthening and knee range of motion is started 3 to 4 weeks postoperatively. Weaning off the brace proceeds gradually, in accordance with the patient’s functional improvement.

- No immobilization is required if only resection was carried out, and patients may gradually begin ambulation when the suction catheters have been removed. Because the lymphatics along the superficial femoral artery and within the buttock remain intact, prolonged swelling is not usually a problem.

OUTCOMES

- Patients who undergo limited resections of the quadriceps muscle usually do not have any residual functional limitations. There are limited data regarding the functional outcomes of patients who undergo extensive resections of the quadriceps muscle with or without reconstruction.

- Markhede and Stener evaluated the postoperative function in 17 patients who underwent quadriceps muscle resections. They found that the isometric strength of the muscle decreased by 22%, 33%, 55%, and 76% when one, two, three, or more components of the quadriceps muscle were resected, respectively.

- Capanna et al reported on the functional effect of quadriceps resection combined with distal femoral resection and prosthetic reconstruction in patients with malignant bone tu-

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**Table 3**

Clinical Data on the Type and Size of Resection and Functional Results of 15 Patients Who Underwent Muscle Transfer Reconstruction of the Extensor Mechanism

<table>
<thead>
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<th>Strength</th>
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F.N., femoral nerve.
mors. They concluded that the degree of quadriceps resection has a strong impact on functional outcome.

- Malawer performed a gait electromyographic analysis on a patient who underwent distal femoral resection, endoprosthetic replacement, and extensor mechanism reconstruction with the sartorius and biceps femoris muscles. Six months after the operation, both muscles were recruiting in phase with the rectus femoris of the same limb.

- According to our experience, most patients who undergo muscle transfer functional reconstruction have good to excellent functional outcomes and satisfactory active range of motion. Reported results of latissimus dorsi functional transplantation are likewise encouraging.

COMPLICATIONS

- Wound dehiscence is usually associated with recent or ongoing postoperative radiation therapy and is easily managed by débridement and skin grafting.
- Vascular injuries rarely occur.
- Knee stiffness is the most common problem and is easily treated by physical therapy.

REFERENCES