BACKGROUND

- Although many bone and soft tissue sarcomas of the femur and thigh can be treated with limb-sparing techniques, some aggressive tumors are complicated by neurovascular involvement or extensive soft tissue contamination and thus require an above-knee amputation (AKA) (FIG 1).
- An AKA is a transfemoral amputation of the lower extremity. AKAs are usually classified by level: high (just below the lesser trochanter), standard or midfemur (diaphyseal), or low distal femur (supracondylar).
- In general, transfemoral amputations with 50% to 70% of the residual bone length (measured from the greater trochanter to the lateral femoral condyle) are optimal. However, when amputations are done in an oncologic setting, the amount of femur remaining is determined by the extent of the tumor.
- Generally if 3 to 5 cm of bone distal to the lesser trochanter remains, a standard AKA prosthesis can still be used.

ANATOMY

- The surgeon must be familiar with the major neurovascular structures of the thigh because these structures will need to be identified and ligated. The femoral artery is the main artery of the thigh and femur. Its course changes throughout the length of the femur, and therefore its location varies depending on the level of amputation (FIG 2).

INDICATIONS

- Local recurrence of malignant carcinoma or sarcoma where limb salvage would not yield a functional limb or effectively remove the disease (FIG 3).
- Tumors with major vascular involvement with invasion of major blood vessels, which usually have poor outcomes and a poor prognosis
- Soft tissue contamination, such as after a pathologic fracture
- Tumors of the distal lower extremity with major nerve involvement, as with tumors of the popliteal space (FIG 4A,B)
- A poorly planned and executed biopsy, which can cause extensive contamination
- Infection, particularly in the case of tumor ulceration
- Skeletal immaturity, which often leads to significant limb-length discrepancies when limb-sparing procedures are done on skeletally immature patients
- Extensive tumor involvement that prohibits adequate soft tissue coverage of a prosthesis (FIG 4C-E)

IMAGING AND OTHER STAGING STUDIES

Plain Radiography
- Plain radiographs often provide the first indication for the need for amputation and an initial estimate of the necessary amputation level.
- Orthogonal views of the femur, tibia, and fibula can be helpful in showing tumor involvement and the extent of bony destruction, although generally up to 30% of the bony architecture has to be destroyed before radiographic findings are apparent (FIG 5A).

Computed Tomography and Magnetic Resonance Imaging
- CT and MRI are the most helpful in determining the level of intramedullary tumor involvement and the extrasosseous extent of the tumor, which is used to determine the amputation level (FIG 5B).
- MRI is also useful for showing tumor involvement of neurovascular structures, which often necessitates amputation. MRI is the most reliable imaging study in determining the presence of skip metastases, which may alter the level of amputation.

FIG 2 • Level of osteotomy and cross-sectional anatomy for supracondylar, diaphyseal, and high above-knee amputation. (Courtesy of Martin M. Malawer.)

FIG 3 • A. A 45-year-old patient initially presented with a dedifferentiated, high-grade osteosarcoma of the fibula. After neoadjuvant chemotherapy the patient underwent intercalary fibular resection. Approximately a year after the surgery the patient presented with a rapidly enlarging, extensive tumor recurrence. B. As shown on MRI, the tumor extensively invaded the superficial posterior, deep posterior, and lateral compartments of the leg. Wide excision of the tumor would necessitate removal of the neurovascular bundle and all three compartments. Above-knee amputation was therefore performed.
FIG 4 • A,B. A 77-year-old patient presented with a high-grade soft tissue sarcoma that invaded the popliteal space and destroyed the proximal and midshaft areas of the tibia and fibula, resulting in the loss of peroneal function. C. A 23-year-old patient with a few years’ history of a neglected benign giant cell tumor of the distal femur with an extensive soft tissue component. D. A plain radiograph of the distal femur showing extensive bone destruction. The knee joint is in flexion contracture due to intractable pain. E. CT shows that only a thin rim of muscles is left. Adequate soft tissue coverage of a prosthesis was therefore not feasible, and above-knee amputation was performed. (C–E: Courtesy of Martin M. Malawer.)

FIG 5 • A. Plain radiograph of the knee showing extensive destruction of the proximal tibia and fibula. B. CT scan showing a large tumor that displaced the popliteal artery posteriorly and obliterated branches of the popliteal artery more distally.
Bone Scan
- Bone scans are useful in determining the intraosseous extent of the tumor; findings correlate well with the MRI.

Angiography and Other Studies
- Angiography is useful in determining the patency of the major vessels. In the older population, the superficial femoral artery is often obliterated.

Biopsy
- A biopsy is necessary before determining the final level of amputation. In general, transmedullary amputation is now performed for bony sarcomas of the distal femur, although historically a hip disarticulation was recommended. A failed limb-sparing procedure of the distal femur can still be treated with a high AKA.

SURGICAL MANAGEMENT
- When AKAs are done for oncologic indications, the tumor extent ultimately determines the level of amputation. Beyond that consideration, retaining as much length as possible that is closest to the ideal stump length will facilitate prosthetic fitting. The types of flaps may vary depending on the extent of the distal femoral tumor; medial-lateral flaps may be required instead of the more traditional fish-mouth incision. The quality of the skin, prior radiation, and old scars must all be considered. In general we do not use immediate-fit prostheses after amputation for tumors.
- When planning the types of flaps that will be used for the amputation, the surgeon should consider the soft tissue extent of the tumor, prior radiation fields, and previous incisions.

Preoperative Planning
- Having patients meet with a prosthetist, a functional amputee, or both can help manage expectations and answer specific questions about daily activities and function.

Positioning
- Patients are placed supine on the operating table with the operative extremity in flexion and abduction (FIG 6).

Approach
- Most amputations are done initially using an anterior approach to the femur. The leg can then be placed in a figure-4 position and then flexed and adducted to facilitate the posterior work.

FIG 6 • The patient is supine; the operated extremity is in flexion and abduction. (Courtesy of Martin M. Malawer.)

Incision and Transection of Muscle, Neurovascular Structures, and Bone
- The most common type of flap is the anterior and posterior fish-mouth flap. This type of incisional line should be drawn before starting the procedure. The initial incision is made through the skin, superficial fascia, and subcutaneous tissue vertical to the skin edges (TECH FIG 1A).
- The major muscles should be carefully transected using electrocautery to reduce bleeding and tacked for later use in soft tissue reconstruction. The level of the amputation will determine the muscles that are transected, but portions of the quadriceps, hamstrings, and adductors are cut at almost all levels (TECH FIG 1B).
- The deep femoral artery and vein are dissected, suture-ligated, and transected.
- Nerves should be pulled gently about 2 cm, ligated with nonabsorbable sutures, and transected with a knife. The sutures can be used later to identify the femoral and sciatic nerves if epineural catheters are to be placed. If the catheters are not placed, the nerves should be allowed to retract back to the muscle mass.
- The bone is cut using an oscillating or Gigli saw. A malleable retractor placed posterior to the femur can prevent damage to the posterior soft tissue and flap. Once the bone is cut, frozen section analysis from the remaining intramedullary canal is performed to ensure that there is no tumor remaining.
- The femoral edge is beveled using a saw or rasp to smooth the remaining edge and to leave a less prominent point of contact for the prosthesis (TECH FIG 1C,D).

Placement of Epineural Catheter and Myodesis
- A small opening is made using a 15-blade scalpel into the epineural sheath. An epineural catheter, which has previously been flushed with 0.25% bupivacaine, is introduced into the epineural space and advanced proximally for 5 to 7 cm. The neural sheath is then closed with 4-0 chromic suture (TECH FIG 2A,B).
- A 16-gauge angiocatheter is introduced into the skin at the desired site of exit for the epineural catheter. The epineural catheter is threaded through the angiocatheter until it is visible beyond the skin. The angiocatheter, encasing the epineural catheter, is carefully brought through the subcutaneous tissue to exit at the skin.
- To prevent flexion and abduction of the femoral stump, drill holes can be made in the femur using a standard drill, and then the sutures used to tag the adductor musculature can be threaded through the femoral holes to tenodese the adductors to the femur. This also helps restore some of the muscular strength (TECH FIG 2C).
A. Incision. The skin flaps are marked. The main factors that determine the type of flaps are the extent of the soft tissue tumor, areas of prior radiation, and previous scars. The highest priority is to avoid local recurrence, and no attempt is made to adhere to standard flaps; at this level a skin or muscle flap of almost any length will heal primarily in a young patient. It is not necessary to use equal flaps; long posterior, anterior, and medial flaps will heal. B. Transection of muscle and bone. Incision is performed through the skin, superficial fascia, and subcutaneous tissue vertical to the skin edges. Using electrocautery, muscles are beveled in their transection down to bone. Large vessels are dissected, suture-ligated in continuity, and transected in a bloodless fashion. Nerves should be gently pulled down from their muscular bed approximately 2 cm, ligated with nonabsorbable monofilament sutures, transected with a knife, and allowed to retract back to the muscle mass. The bone is transected with an oscillating or Gigli saw without traumatizing the soft tissues. C. The femoral edge should be beveled and smooth. D. A sharp edge can become extremely painful, especially when pressure from a prosthesis is applied. (Courtesy of Martin M. Malawer.)

We recommend excising some of the adductors before myodesis to shape the stump into a nice conical shape. Additional muscle may be resected from the lateral aspect of the thigh if necessary. A plug of polymethylmethacrylate (PMMA) or Gelfoam is placed in the distal canal to prevent large hematomas from occurring due to continuous intraosseous bleeding after surgery. This is more common in young adults and children. The remaining quadriceps and hamstring muscles are myodesed to each other to cover the end of the femur.

**Drain Placement and Closure**

- Closed suction drains placed beneath the fascial layer should be brought out of the medial and lateral aspects of the incision (TECH FIG 3A).
- The superficial fascia should be tightly closed. As the skin edges are closed, the surgeon should take care to avoid having excess tissue and large skin folds, which can later interfere with optimal prosthetic fitting.
- A rigid dressing should be applied at the completion of the amputation to reduce swelling and prevent the development of a flexion contracture (TECH FIG 3B).
TECH FIG 2 • A. An epidural catheter, flushed with bupivacaine 0.25%, is introduced into the epineural space. The catheter is advanced 5 to 7 cm proximally, and the neural sheath is sutured over the catheter with absorbable sutures. B. An epineural catheter in the femoral nerve after above-knee amputation. Contrast dye was bolus injected to show the distribution of local anesthetics within the epineural space. C. A two-layer myodesis is used over the end of the femur. Muscle stabilization of the femur is essential if the strength of the limb is to be retained. The quadriceps and hamstring muscles are myodesed to each other to cover the bony end of the femur, and the adductors are tenodesed to these muscles and the femoral stump using drill holes. This is especially important if there is a short proximal femoral stump, which tends to go into flexion and abduction. (Courtesy of Martin M. Malawer.)

TECH FIG 3 • A. Closed suction drains are brought out of the medial and lateral aspects of the incision. It is important not to stitch these catheters to the skin, because they will be removed from inside the rigid dressing. B. Application of a rigid dressing. (Courtesy of Martin M. Malawer.)
PEARS AND PITFALLS

| Postoperative flexion contracture | Flexion contractures can be prevented with the use of proximal casting or immobilization to the groin level, suspended in place with a belt, if necessary. |
| Adductor myodesis | After AKA the iliopsoas and hip abductors can cause the stump to go into flexion and abduction. Tenodesing the adductor magnus prevents this deformity and helps prevent the loss of hip adduction power, which has been estimated to be up to 70% less without myodesis. Myodesis acts as an insertion site and facilitates muscle contraction and function. |
| Muscle balance | Managing muscle group imbalances through myoplasty also improves the function of the amputee. Because the hip flexors are stronger than the extensors, the hamstrings should be cut longer than the quadriceps and attached to one another. |
| Neurona | Nerves should be cut as proximally as possible and buried within muscular tissue to prevent neuroma formation. |
| Phantom pain | The use of epineural catheters in the femoral and sciatic nerves can decrease the incidence and severity of phantom pain. |
| Skin pressure from bone edges | The distal anterior cortical edge of the femur should be beveled to prevent pressure arising from the bone, particularly with prosthetic use. |

POSTOPERATIVE CARE

- A compressive dressing applied to the stump site diminishes postoperative swelling at the stump site.
- Proximal extension of the postoperative immobilizer or splint, prone positioning, and physical therapy help to prevent flexion contracture.
- Fitting for an initial or temporary prosthesis soon after wound healing and swelling resolution is most often associated with increased prosthetic use.
- Because the energy requirements of AKAs are about 60% to 100% times greater than that required for non-amputees, many amputees require the use of assistive devices for ambulation.
- Phantom limb pain and sensations can diminish after surgery. However, when phantom pain persists, narcotics and drugs with effects on nerves such as gabapentin (Neurontin) may be helpful.

OUTCOMES

- Through effective multidisciplinary care, most patients are able to ambulate and return to normal daily activities, including driving. Some are also able to participate in sporting activities.
- Outcome studies comparing patients treated with amputations versus those treated with limb salvage found that AKA amputees were more limited in their mobility and community activities compared to those with limb salvage, but they reported less muscle weakness. In general, AKA amputees have approximately the same overall quality of life compared to patients undergoing limb-sparing surgery when assessed by numerous psychological measures.
- AKA amputees have also been shown to be more likely to walk with a limp.

COMPLICATIONS

- Wound healing problems can arise but are not as common as in amputations performed for vascular or ischemic problems. Wound problems after amputations performed for tumors are most likely due to preoperative host factors such as comorbidities and nutritional status. Therefore, the patient’s preoperative status should always be optimized where possible.
- Phantom pain or causalgia syndromes may occur and are difficult to predict, although patients with significant preoperative pain complain of postoperative pain more often. Attempts at preventive anesthesia (eg, serial epidurals before surgery) have produced mixed results. It is important to identify and diagnose these painful syndromes early and manage them aggressively.

REFERENCES