BACKGROUND
- The femur is the most common site for metastatic bone disease requiring surgery. Because it is a major weight-bearing bone with minimal space for surgical errors, the operative procedure must be carefully planned and meticulously executed, with the aim of achieving durable reconstruction. Detailed pre-operative clinical and imaging evaluation is essential to define the morphologic characteristics of the lesion that validate surgical intervention and to distinguish between lesions that can be managed with curettage and cemented fixation and those that require resection with endoprosthetic reconstruction.1,6,7
- Unlike primary sarcomas of the femur, metastatic tumors usually have a small soft tissue component, even in the presence of extensive bone destruction. This feature allows the sparing of extracortical structures, such as the joint capsule, overlying muscles, and muscle attachments, and the possibility of applying them for reconstruction and preservation of function.
- Because of distinctive differences in anatomic and surgical considerations, surgeries around the proximal femur, femoral diaphysis, and distal femur will be discussed separately (FIG 1).

ANATOMY
Proximal Femur
- A thick joint capsule encircles the femoral head and neck and attaches to the base of the neck.
- Key elements at the lateral aspect: The greater trochanter is the insertion site for the gluteus medius muscle (lateral stabilizer and hip abductor) and the origin for the vastus lateralis muscle.
- Key elements at the medial aspect: The minor trochanter is the insertion site for the psoas muscle (medial stabilizer and hip flexor).

Femoral Diaphysis
- The femoral diaphysis is encircled by two muscle layers:
  - First layer: the vastus intermedius muscle
  - Second layer: The rectus femoris and vastus medialis muscles intersect at the anteromedial aspect, and the rectus femoris and the vastus lateralis muscles intersect at the anterolateral aspect.

Distal Femur
- The medial femoral condyle is positioned below the insertion site of the vastus medialis muscle.
- The lateral femoral condyle is positioned below the insertion site of the vastus lateralis muscle.

INDICATIONS
- Pathologic fracture
- Impending pathologic fracture (FIG 2)
Intractable pain associated with locally progressive disease that has shown inadequate response to narcotics and radiation therapy
- Solitary bone metastasis in selected patients and tumor types (e.g., those with breast cancer and renal cell carcinoma)

**IMAGING AND OTHER STAGING STUDIES**
- Plain radiographs of the entire femur are mandatory to rule out coexisting metastases that may influence the extent and technique of surgery. CT of the lesion will clearly define the extents of soft-tissue component and bone destruction. Total body bone scintigraphy is done to detect coexisting metastases elsewhere in the skeleton (FIG 3). The results of imaging should provide the surgeon with answers to the following questions:
  - Is the lesion an impending fracture? (If not, it should probably be treated nonoperatively).
  - Are there additional femoral metastases? If so, can they be managed by nonoperative techniques or do they also require surgery?
  - What is the appropriate surgical approach? As a rule, tumor curettage with cemented fixation is indicated for lesions in which the remaining cortices allow containment of the fixation device. Otherwise, surgery consists of resection of the affected bone segment with prosthetic reconstruction.

**FIG 3**
- **A.** Plain radiograph showing a metastatic lesion of the proximal femur. The surrounding cortices are intact. Surgery consisted of curettage and reconstruction with a cemented intramedullary nail.
- **B.** Metastatic lesion at the same site with extensive circumferential bone destruction. Surgery in this case entailed resection of the proximal femur and reconstruction with an endoprosthesis. Anteroposterior plain radiograph (C) and computed tomography (D) of the distal femur showing a metastatic lesion at the left medial femoral condyle. The lateral condyle and articular cartilage are preserved and form an anatomic continuum, which allows the fixation of a cemented reconstructive device.
- **E** and lateral (F) plain radiographs and computed tomography (G) of the distal femur showing a large metastasis with destruction of the entire anterior aspect of the bone and considerable thinning of the posterior cortex. Surgery included resection of the distal femur and reconstruction with an endoprosthesis.
PROXIMAL FEMUR

Position and Incision

- The patient is placed supine on the operating table, with the buttock of the affected side close to its edge. The operating table is positioned in a 30-degree tilt away from the surgeon.

- A straight longitudinal incision is made along the tip of the greater trochanter and femoral diaphysis (TECH FIG 1). It should begin 5 cm proximal to the greater trochanter to allow the introduction of a femoral nail and 5 cm below the lower edge of the lesion to enable adequate tumor curettage.

Exposure

- The fascia lata is divided longitudinally and retracted to expose the lower edge of the gluteus medius muscle and its insertion site at the greater trochanter muscle, the vastus ridge, and the upper part of the vastus lateralis muscle (TECH FIG 2A,B).

- Using electrocautery, the vastus lateralis muscle is detached from the vastus ridge and the lower aspect of the proximal diaphysis and reflected anteriorly to expose the diaphyseal cortex (TECH FIG 2C-E). A longitudinal cortical window with oval edges is made below the vastus ridge (TECH FIG 2F).

Tumor Removal

- Gross tumor is removed with hand curettes (TECH FIG 3A,B). Curettage should be meticulous and should leave only microscopic disease in the tumor cavity. It is followed by high-speed burr drilling of walls of the tumor cavity (TECH FIG 3C,D). (continued)
TECH FIG 2 • (continued) F. A cortical window is made below the vastus ridge.

TECH FIG 3 • A,B. Gross tumor is removed with hand curettes. C,D. Curettage is followed by high-speed burr drilling of the walls of the tumor cavity. E. The gluteus medius muscle is detached and reflected from its insertion site at the greater trochanter muscle. (continued)
When a proximal femur resection is done, the gluteus medius muscle is detached and reflected from its insertion site at the greater trochanter muscle (TECH FIG 3E), the joint capsule is opened and the femoral head is dislocated from the acetabulum, the medial aspect of the proximal femur is freed of muscle attachments, and then an osteotomy is performed below the lower aspect of the tumor (TECH FIG 3F–H).

Mechanical Reconstruction

- Reconstruction begins with the introduction of an intramedullary nail. After proper positioning and length are verified, the nail is partially withdrawn and the entire tumor cavity is filled with cement (TECH FIG 4A). The nail is then pushed back into the medullary canal and fixed with interlocking screws (TECH FIG 4B,C). Alternatively, a side plate and a sliding screw can be sim-
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 Similarly used for reconstruction. After resection of the proximal femur, a cemented tumor prosthesis is used to reconstruct the bone defect (TECH FIG 4D).

Soft Tissue Reconstruction and Wound Closure

- The origin of the vastus lateralis muscle is reattached to the vastus ridge (TECH FIG 5A). If endoprosthetic reconstruction had been carried out, the remaining hip capsule is sutured tightly with a 3-mm Dacron tape around the neck of the prosthesis, forming a noose that provides immediate stability. The capsule is reinforced by rotating the external rotator muscles proximally and suturing them to its posterolateral aspect. The remaining abductor tendon is attached to the lateral aspect of the prosthesis through a metal loop, and the psoas muscle is attached to the medial aspect of the prosthesis at the level where the lesser trochanter had been (TECH FIG 5B).

- It is important to attach these two muscles to the prosthesis so that balanced function will be achieved. The surgical wound is then closed over suction drains and the patient is placed in balanced suspension or in tibial pin traction with the hip elevated and flexed 20 degrees. An abduction pillow can also achieve the correct positioning.

Postoperative Care

- Continuous suction is required for 3 to 5 days, and perioperative intravenous antibiotics are continued until the drainage tubes are removed. If tumor curettage had been done, rehabilitation should include early ambulation with unrestricted weight bearing as well as passive and active range of motion of the hip joint.

- After wound healing, usually 3 to 4 weeks after surgery, the patient is referred for adjuvant radiation therapy. Adjuvant radiation therapy is usually not required in patients who underwent proximal femur resection with endoprosthetic reconstruction.

- If endoprosthetic reconstruction had been done, the extremity is kept in balanced suspension for at least 5 days. Postoperative mobilization with total hip replacement precautions with or without an abduction brace and weight bearing as tolerated are continued for 6 weeks.

FEMORAL DIAPYSIS

Position and Incision

- The patient is placed supine on the operating table, with the buttock of the affected side close to its edge. The operating table is positioned in a 30-degree tilt away from the surgeon.

- A diaphyseal lesion with a lateral cortical breakthrough is approached using a longitudinal incision along the anterolateral aspect of the thigh at the level of the interface between the rectus femoris and vastus lateralis muscles, with the lesion located at the center of the incision.

- A lesion with medial cortical destruction is similarly approached using an anteromedial incision at the level of the interface of the rectus femoris and vastus medialis.
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Exposure

- The interval between the rectus femoris and vastus medialis muscles is opened, and the muscles are retracted to expose the vastus intermedius overlying the femoral diaphysis. The vastus intermedius is split longitudinally to expose the femoral diaphysis, and retractors are placed behind it (TECH FIG 6). This approach allows wide exposure of the affected bone with minimal injury to the overlying muscles. A longitudinal cortical window with oval edges is made above the lesion.

Tumor Removal

- Gross tumor is removed with hand curettes (TECH FIG 7A,B). Curettage should be meticulous and should leave only microscopic disease in the tumor cavity. This is followed by high-speed burr drilling of the walls of the tumor cavity (TECH FIG 7C,D).

Mechanical Reconstruction

- Reconstruction begins with the introduction of an intramedullary nail either antegrade or retrograde, depending on the location of the lesion along the diaphysis. After proper positioning and length have been verified, the nail is partially withdrawn and the entire tumor cavity is filled with cement (TECH FIG 8). The nail is then pushed back into the medullary canal and fixed with interlocking screws.

Soft Tissue Reconstruction and Wound Closure

- A suction drain is positioned along the femoral diaphysis muscle, and the vastus lateralis muscle is sutured to the rectus femoris muscle.

TECH FIG 6 • The tumor is approached using the interval between the rectus femoris and vastus medialis muscles. The vastus intermedius is split to expose the underlying cortex, and an oval cortical window is made.

TECH FIG 7 • A,B. Gross tumor is removed with hand curettes. C,D. Curettage is followed by high-speed burr drilling of the walls of the tumor cavity.
An intramedullary nail is introduced and adequate positioning is verified. The nail is then partially withdrawn, the tumor cavity is entirely filled with cement, and the nail is reintroduced through the cement and secured with interlocking screws.

**Postoperative Care**
- Continuous suction is required for 3 to 5 days, and perioperative intravenous antibiotics are continued until the drainage tubes are removed. Rehabilitation should include early ambulation with unrestricted weight bearing as well as passive and active range of motion of the knee joint.
- When wound healing is complete, usually 3 to 4 weeks after surgery, the patient is referred for adjuvant radiation therapy.

**DISTAL FEMUR**

**Position and Incision**
- The patient is placed supine on the operating table, with the affected knee flexed 30 degrees.
- A medial condyle lesion is approached using a longitudinal incision along the anteromedial aspect of the distal thigh at the level of the interface between the rectus femoris and vastus medialis muscles and 1 cm away from the medial border of the patella (TECH FIG 9).
- A lesion of the lateral condyle is similarly approached using an anterolateral incision at the level of the interface of the rectus femoris and the vastus lateralis and lateral to the patella.

**Exposure**
- The interval between the distal aspect of the vastus medialis and rectus femoris muscles is opened and the insertion of the vastus medialis to the quadriceps tendon, patella, and joint capsule is detached (TECH FIG 10A,B). The vastus medialis muscle is retracted posteriorly, exposing the underlying vastus intermedius muscle and the distal femur (TECH FIG 10C,D).
- A lesion at the lateral femoral condyle is approached using similar detachment and posterior reflection of the vastus lateralis muscle. This approach allows wide exposure of the affected bone with minimal injury to the overlying muscles. A longitudinal cortical window with oval edges is made above the lesion.

**Tumor Removal**
- Curettage. Gross tumor is removed with hand curettes (TECH FIG 11A,B). Curettage should be meticulous and should leave only microscopic disease in the tumor cavity. It is followed by high-speed burr drilling of walls of the tumor cavity (TECH FIG 11C,D).
- Distal femoral resection (see Chapter ON-25). TECH FIG 11E,F show the release of the vastus medialis and the popliteal exposure. TECH FIG 11G,H show the release of all soft tissues around the distal femur and the femoral osteotomy. The cavity is reconstructed by a combination of intramedullary and plate fixation followed by cement (PMMA). See TECH FIG 12A.
**TECH FIG 10 • A, B.** The vastus medialis muscle is detached from its attachment to the rectus femoris muscle and inserted into the quadriceps tendon, patella, and joint capsule. C, D. The vastus medialis muscle is retracted posteriorly, exposing the vastus intermedius muscle and distal femur.

**TECH FIG 11 • A, B.** Gross tumor is removed with hand curettes. (continued)
TECH FIG 11 • (continued) C,D. Curettage is followed by high-speed burr drilling of the walls of the tumor cavity. E,F. The medial gastrocnemius muscle is detached and reflected, exposing the popliteal fossa. The posterior femur is isolated by ligation and transection of the geniculate vessels. G. The joint capsule is opened and released circumferentially from the femur. H. A distal femur osteotomy is done 1 to 2 cm beyond the point of proximal tumor extension.
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A distal femur osteotomy is carried out at the appropriate location as determined by the preoperative imaging studies: 1 to 2 cm beyond the point of proximal tumor extension is generally appropriate for metastatic tumors (TECH FIG 11H–J). A tibial osteotomy is then done to allow the introduction of the prosthetic tibial component.

**Mechanical Reconstruction**

- A combination of a cemented intramedullary nail and a condylar plate achieves optimal stability and is preferred for reconstruction (TECH FIG 12A–C). After resection of the distal femur, a cemented tumor prosthesis is used for reconstruction (TECH FIG 12D–F).

**Soft Tissue Reconstruction and Wound Closure**

- Suction drains are positioned along the femoral diaphysis, and the vastus medialis muscle is sutured to the rectus femoris muscle and its insertion sites along the quadriceps and patella. The medial gastrocnemius muscle is pulled up and sutured to the vastus medialis muscle (TECH FIG 13).

**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 tumor curettage had been done, rehabilitation should include early

**TECH FIG 12 • A–C.** A cemented intramedullary nail and a condylar plate are used to reconstruct metaphyseal lesions in which the remaining cortices allow containment of the fixation devices. D–F. A cemented tumor prosthesis is used for reconstruction after resection of the distal femur.
The vastus medialis muscle is sutured to the rectus femoris muscle and its insertion sites along the quadriceps and patella. The medial gastrocnemius muscle is pulled up and sutured to the vastus medialis muscle.

Ambulation with unrestricted weight bearing as well as passive and active range of motion of the knee joint. When the wound is healed, usually 3 to 4 weeks after surgery, the patient is referred for adjuvant radiation therapy. In the case of distal femur resection, the lower extremity is elevated for 3 days, until the first postoperative wound check, to prevent wound edema. Knee motion is restricted in an immobilizing brace for 2 to 3 weeks to allow healing of the surgical flaps and until the extensor mechanism is again functional. During that time, isometric exercises are carried out and weight bearing is allowed. Adjuvant radiation therapy is usually not required in patients who underwent distal femur resection with endoprosthetic reconstruction.

**PEARLS AND PITFALLS**

**Proximal femur**
- Adequate imaging of the entire femur: allows the surgeon to decide whether to perform tumor curettage or resection with endoprosthetic reconstruction
- Wide exposure of the tumor cavity, using an adequately positioned and large cortical window.
- Meticulous curettage and burr drilling
- Reconstruction with hardware and cementation of the entire volume of the cavity
- Proximal femur resection: reconstruction with cemented implant, suturing of the joint capsule, and reattachment of the gluteus medius and psoas muscles
- Early ambulation and range-of-motion exercises; weight bearing as tolerated

**Femoral diaphysis**
- Exposure through the interval between the rectus femoris and vastus lateralis or medialis
- Wide exposure of the tumor cavity using an adequately positioned large cortical window
- Meticulous curettage and burr drilling
- Reconstruction with hardware and cementation of the entire volume of the cavity
- Early ambulation and range-of-motion exercises; weight bearing as tolerated

**Distal femur**
- **Intraoperative**
  - Exposure through the interval between the vastus medialis and lateralis and the rectus femoris
  - Wide exposure of the tumor cavity using an adequately positioned large cortical window
  - Meticulous curettage and burr drilling
  - Reconstruction with a cemented intramedullary nail and a condylar plate
  - When distal femur resection is indicated, the gastrocnemius origin is detached to expose the popliteal fossa.
  - Reconstruction is done with a cemented tumor prosthesis.
- **Postoperative**
  - Early ambulation and weight bearing as tolerated
OUTCOMES AND COMPLICATIONS

- Functional outcomes and common complications of prosthetic replacements for metastatic bone disease are no different from those with the same operations for primary sarcomas of bone (see Chapters ON-25 and ON-26). Because of the short life expectancy of most patients with metastatic bone disease, however, the problems seen at long-term follow-up, such as aseptic loosening, the wearing down of polyethylene components, and fatigue prosthetic fractures, are rarely seen.

- The real concerns in the setting of metastatic bone disease are local tumor recurrence and failure of reconstruction. Meticulous tumor removal, proper selection and use of fixation devices, and adjuvant radiation therapy have made these complications rare: local recurrence and reconstruction failures are seen in less than 5% of the patients.

REFERENCES

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