Chapter 39
Creating an Above-Knee Amputation Stump After Hip Disarticulation
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BACKGROUND
- Orthopaedic oncology has made dramatic advances in the past 25 years by developing limb-sparing surgery to the point where 85% to 95% of the patients can be treated with complete resection of their disease while preserving the limb and its function.2 Despite these recent advances in limb-sparing surgery, approximately 10% of all femoral sarcomas are not amenable to limb-salvage techniques and require an amputation. Disarticulation of the hip for malignant tumors is a rare operation, but it is still needed instead of an above-knee amputation if the tumor cannot be resected using a limb-salvage procedure due to proximal transosseous skip metastases, pathologic fractures, extensive diaphyseal extension, and adjacent soft tissue masses combined with poor response to adjuvant chemotherapy.1,5
- Functional outcome after hip disarticulation is problematic. Jain et al8 published their results of 80 hip disarticulations. Function on the whole was poor, with only one surviving patient regularly using an artificial limb. Patients after hip disarticulation are left without a leg and without a fulcrum to move an artificial limb. They are likely to suffer loss of self-esteem as well as loss of function and mobility, and they may well suffer from phantom pains.
- The energy expenditure during mobility after an amputation is much greater than that without an amputation and increases as the amputation level becomes more proximal.3 The energy expenditure after a hip disarticulation is reported to be 82% greater than that required by a non-amputee.7 In comparison, the energy expenditure after a long below-knee amputation is only about 10% more than that required by a non-amputee. When a patient with a hip disarticulation attempts to use a prosthesis, the energy requirements can then be as much as twice that of a normal ambulator. Those who cannot overcome these significant energy requirements must adapt to the use of crutches, canes, or a wheelchair. Given these factors, any intervention that can reduce the energy expenditures required of amputees might increase their likelihood of mobility and improve their overall quality of life.
- By preserving the soft tissues of the proximal thigh when amputating the leg at the level of the hip joint, it is possible to reconstruct a functional proximal thigh stump with a proximal femur prosthesis. This is a rare procedure with only few indications, but it remains an important option due to its benefits over a standard hip disarticulation.
- Preserving hip function is the main advantage of stump prosthesis reconstructive surgery after hip disarticulation. The main disadvantages of a hip disarticulation are its unappealing appearance; the discomfort of the basket-shaped prosthetic socket, which incorporates nearly half of the pelvis; and the 82% increase in energy consumption required for walking compared with that in a normal person.5
- The stump prosthesis provides a lever arm for hip joint motion. This dramatically lowers the energy consumption of ambulating with a prosthetic limb and thus increases the likelihood of prosthetic use.
- The first attempt to improve the functional status of patients requiring hip disarticulation for malignant bone tumors was published by Marove, McMillian, and Nasr in 1979.3 They used an Austin-Moore prosthesis (Smith and Nephew, Memphis, TN) to convert a hip disarticulation to an above-knee amputation. Over the years, the senior author has used this basic idea and made modifications to develop a technique that involves complete tumor removal and resection of the entire femur (hip disarticulation) followed by reconstruction of a proximal thigh stump (similar to an above-knee amputation stump) using a custom modular “stump” endoprosthesis.

INDICATIONS
- Indications for stump prosthesis reconstructive surgery after tumor resection are as follows (FIG 1):
  - Skip metastasis to proximal femur from a primary distal femur osteosarcoma
  - Inability to achieve safe osseous margins with a typical wide resection or above-knee amputation due to tumor extension (the most common indication)
  - Tumor contamination of the proximal medullary canal after pathologic fracture due to tumor in the distal femur and retrograde intramedullary fixation
  - A prerequisite for the operation is uncontaminated soft tissues around the hip, retrogluteal region, and proximal thigh.

IMAGING AND OTHER STAGING STUDIES
Plain Radiography
- Hip and pelvic imaging to rule out pelvic involvement
- Radiographic analysis of the entire femur

Computed Tomography and Magnetic Resonance Imaging
- Pelvic and hip CT scans are done to locate and define the tumor margins. CT helps rule out tumor involvement of the acetabulum.

Bone Scan
- A bone scan of the femur is done to determine the extent of the skip metastasis.

Angiography and Other Studies
- MRI of the soft tissue of the pelvis and proximal femur is a crucial part of the decision as to whether enough soft tissue
can be safely spared to reconstruct the proximal thigh stump with adequate soft tissue coverage.

**Surgical Management**
- Unique anatomic considerations:
  - Arterial blood supply to the soft tissues must be preserved. The superficial femoral artery should be ligated within the sartorial canal as distally as oncologically possible.
  - The prosthesis must be secured to the hip capsule to avoid dislocation aggravated by gravity pulling on the prosthesis. This requires capsular reconstruction and reinforcement.
  - Modular prosthetic design allows use of a large bipolar cup, modular body length with porous coating to aid in soft tissue ingrowth, and a distal rounded tip designed to avoid tissue penetration with distal muscle fixation holes (FIG 2).
  - Muscle groups of the thigh must be connected distally to the prosthesis with tension balanced properly to avoid the excessively strong pull of the hip flexors and abductors.

**FIG 1** • Indications for hip disarticulation and reconstruction with a stump prosthesis. **A.** Proximal skip metastasis without soft tissue extension. **B.** Corresponding resected pathology gross specimen as seen in **C.** **C.** Plain radiograph of a distal femoral nonunion after a pathologic fracture that was treated with a long retrograde intramedullary nail. **D.** Distal femoral synovial sarcoma with a proximal femoral head skip metastasis.

**FIG 2** • A modular stump prosthesis consists of a proximal bipolar head, porous coating, and holes to reconnect the hip capsule and abductor mechanism. The prosthesis body comes in different lengths. The distal tip is rounded to avoid penetration of tissues. Distal holes are used to anchor down the distal muscle ends.
■ Sufficient soft tissue coverage of all the prosthesis, and specifically its distal part, is critical.
■ Phantom pain and stump pain should be addressed initially by placing an epineural catheter in the transected sciatic nerve and using multimodal analgesia.

Preoperative Planning
■ MRI and CT are done to determine the extent of the tumor in the proximal femur.

HIP EXPOSURE AND VASCULAR DISSECTION
■ The patient is placed supine on the operating table. A two-armed incision is made starting medially and extending distally along the medial side of the distal femur. This incision should be relatively posterior so that the sartorial canal and the superficial femoral artery are accessed through their posterior aspect, leaving the anterior branches to supply the anterior flap and quadriceps muscle (similar to an anterior flap hemipelvectomy). The lateral portion of the incision is directed toward the greater trochanter and extends down the lateral portion of the femur in line with the course of the fascia lata.
■ The incision and approach to the hip may vary depending on the type of flap. The initial incision is carried down through the subcutaneous fat and fascial layer to reveal the external oblique aponeurosis using large anterior myocutaneous flaps (TECH FIG 1). Multiple branches of the saphenous vein are usually encountered; these should be clamped, divided, and ligated.
■ Once the superficial femoral artery is identified, it is clamped, divided, and ligated as distally as oncologically possible. The accompanying vein and nerve are also ligated. The sartorius is identified at its origin at the anterior superior iliac spine and divided from its origin.
■ The hip is flexed to relax the iliopsoas muscle, which is identified and dissected from its origin.

Anterior Flap Dissection
■ Large anterior and posterior flaps are developed. The fascia lata is incised along its entire length. The vastus lateralis is released from its origin.

Hip Disarticulation
■ A trochanteric osteotomy is made with the abductors detached with the osteotomy fragment. The osteotomy is recommended as long as there is no tumor involving the greater trochanter and surrounding area. An appropriate angle should be maintained while the osteotomy is being performed to ensure that an adequate amount of bone remains attached to the abductor musculature.
■ The short external rotators are divided at their bony insertions.
■ The hip capsule is identified and divided at the base of the femoral neck using a standard T-type incision. The base of the T runs along the anterior part of the neck. The T itself is circumferential along the base of the neck.
■ The hip capsule is tagged for later reconstruction.
■ The sciatic nerve is located at the level of the hamstring. It should be cut 2 cm proximal to where the hamstrings are cut. By maintaining the proximal sciatic branches, innervation to the hamstrings is maintained and thus hip extension is preserved. The hip is disarticulated at the acetabular level at this point and the entire femur is removed (TECH FIG 2).

Creating a Femoral Stump with a Proximal Femoral Modular Prosthesis
■ The proximal femoral modular prosthesis comprises a proximal bipolar part, a body, and a distal rounded tip. The proximal bipolar part has holes and porous coating around the base of the neck that is intended for reattaching the hip capsule and the greater trochanter. This prevents sliding of the transferred muscles.
■ The prosthesis body has variable length options. The correct length is chosen according to trial measurements.
■ The distal conical tip is custom-made to fit the prosthetic body. It has a rounded bullet-shaped tip to avoid pene-
The whole proximal femur is exposed, disconnected from the hip capsule, and removed. Muscle ends and hip capsule are tagged as they are disconnected.

Trial measurements of the stump prosthesis. Bipolar cup size may be adjusted to fit the acetabular diameter. Body length is measured so that when muscle groups (quadriceps, hamstrings, and adductors) are reconnected distally, even tension and a neutral position of the limb are achieved.

The hip capsule that had been tagged at the time of resection is reconstructed and attached to the proximal part of the prosthesis. The psoas muscle is reattached on the anterior aspect of the capsule and the external rotators are reattached to the posterior capsule.

To strengthen the capsular closure, we use 3-mm Dacron tape, which acts as a noose around the prosthesis to prevent dislocation. This step is often easier if done just before the actual prosthesis placement.

The Dacron tape is sewn circumferentially around the cut capsule (TECH FIG 4). Putting too much tension on the Dacron tape may cause difficulty in reducing the prosthesis. Once the Dacron is in place, the assembled prosthesis is reduced into the acetabulum and the Dacron is snugly tightened and tied, forming a noose around the femoral neck. In our experience this has helped to prevent dislocations.

The hip joint should be put through functional range of motion to ensure a successful outcome.

Once the surgeon is satisfied with the prosthesis and range of motion, the previously detached iliopsoas muscle is pulled over the anterior hip capsule and sutured to it with Ethibond. The short external hip rotators are pulled anteriorly and sutured to the posterior capsule.
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Techniques

Reconstruction of the Adductor and Abductor Mechanism

- The hip abductors with the osteotomized greater trochanter are repositioned and reconnected with cables and a greater trochanter grip (TECH FIG 5A). The adductors are reconnected to the stump stem (TECH FIG 5B,C).

- The remaining proximal portion of the sciatic nerve is identified. Its epineural sheath is opened carefully using a fine right-angle clamp, and a standard epidural catheter is placed and threaded proximally for at least 5 to 10 cm within the sheath. The catheter is then sutured to nearby adipose or muscular tissue to help secure it using a 4-0 chromic suture. A 14-gauge angiocatheter is placed at the desired exit point for the catheter, with the needle passing beneath the subcutaneous and muscular layers. The epineural catheter is threaded through the angiocatheter to its desired position at the skin level and the angiocatheter is removed with the epineural catheter now outside the skin. The catheter should be infused with 4 to 8 cc 0.25% bupivacaine without epinephrine to aid in postoperative pain control.

Soft Tissue Reconstruction and Wound Closure

- Dacron tapes are sutured into all cut distal stumps of the quadriceps, adductors, and hamstrings (TECH FIG 6).

- The posterior muscle groups are tenodesed to the stump prosthesis using the holes made into the distal portion of the prosthesis with the hip in complete extension. The quadriceps muscle is tenodesed to the anterior portion of the stump prosthesis in a similar fashion through the preformed holes, also with the hip in extension. The adductor group is connected in a similar fashion. By setting the prosthesis in neutral position and pulling all three groups and tenodesing them at once, muscle balance is achieved.

- The surgeon should avoid hip flexion and adduction.

- The ends of the muscles are sutured to each other, forming a continuous fascial border covering the distal stump. Appropriate muscle tensioning and balancing are imperative to prevent muscle contractures, particularly abduction and adduction or flexion contractures.

- The reconstructed stump should lie in neutral position. The origin of the vastus lateralis is reattached to the greater trochanter proximaly. The vastus lateralis fascia is tenodesed to the fascia lata.

- We favor the use of two Jackson-Pratt drains to drain the wound at the deep layers of the hip joint and the distal stump (TECH FIG 6D).

- The fascia lata is reapproximated along its entire length. The subcutaneous and skin layers are then closed using standard techniques.

- A compressive dressing is recommended to prevent excessive swelling. The stump should remain in neutral position if the tissue tension is balanced correctly.
Fasciocutaneous flaps to supply adequate cover
- An anterior flap is preferred, but if this is not possible then a posterior flap is used.

Sparing the abductor mechanism with a greater trochanter osteotomy
- As long as no disease involves the area of the greater trochanter, this should be osteotomized and used in reconnecting the abductor mechanism.

Trial prosthesis
- Measurements should be made intraoperatively for the bipolar head size and body length of the prosthesis.

Hip capsule
- Hip joint capsule should be preserved and tagged. After resection the capsule should be reconnected to the prosthesis around the base of the neck. The hip capsule is then reinforced by connecting the distal end of the psoas muscle to the anterior capsule and the short external rotators to the posterior capsule.

Muscle tension
- The quadriceps, hamstrings, and adductor muscles should be reconnected at equal tension while the prosthesis is in neutral position.

Sciatic epineural catheter
- Postoperative analgesia is crucial. We believe pain should be treated perioperatively by inserting an epineural catheter into the transected tip of the sciatic nerve.

TECH FIG 6 • The distal muscle ends are tagged at the time of resection. Reconstruction consists of balancing between flexor and extensor muscles and between the adductors and abductors. These are all reconnected to the distal end of the prosthesis and to each other. Technically this is done with the prosthesis in neutral position. A,B. The quadriceps, hamstrings, and adductor muscle groups are pulled and attached to the prosthesis with even tension. The muscle ends are then connected to one another at their distal ends. C,D. When connected correctly, the prosthesis remains in neutral position as the patient awakens on the operating table.
POSTOPERATIVE CARE

- Drains may be removed about 3 days after surgery. Compressive dressings are used for the first few weeks after surgery. A prosthesis may be fitted as soon as the wound has healed. Full weight bearing is permitted.
- Physiotherapy may begin promptly after surgery and should focus on achieving range of motion.

OUTCOMES

- We have used this procedure in six patients over a 30-year period for osteosarcoma (n = 2), malignant fibrous histiocytoma of bone (n = 2), and synovial sarcoma (n = 2), with very good results. Five of the six patients ambulated with an above-knee prosthesis (FIG 3). The only patient who did not ambulate with his prosthesis died within several months of the surgery due to complications from his disease.
- There were no infections, no dislocations, and no local recurrences; no secondary procedures were required in any of these patients.
- Three patients died of their disease and three patients remain alive. Of the three remaining patients, one has been ambulating with his stump prosthesis for 15 years.

COMPLICATIONS

- A possible complication is deep infection involving the prosthesis. Stump reconstruction should be undertaken only when it is evident there is no infection of the limb. If there is doubt about infection, a two-stage procedure is recommended.
- To avoid hip dislocation, the hip joint capsule must be reconstructed. The reconstructed hip is then reinforced with the psoas anteriorly and the short external rotators posteriorly. Stability should be assessed intraoperatively.
- There is a natural tendency for the stump toward flexion and abduction due to the muscle strength of the quadriceps and abductors. It is therefore crucial to achieve muscle balance of the quadriceps, adductors, hamstrings, and abductors during reconstruction.

REFERENCES