Proximal Tibial Resection and Prosthetic Reconstruction

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Summary: Proximal tibia resection with endoprosthetic reconstruction is a complex limb sparing procedure for tumors of the proximal tibia. Recent advances in implants and surgical techniques have made this option preferable to amputation for many patients. Long-term survival and recurrence rates are similar between limb salvage and limb ablation in the proximal tibia. Appropriate indications for limb salvage are imperative to mitigate disastrous outcomes such as loss of limb or life. A comprehensive perioperative evaluation should include a detailed history and physical, laboratory, and radiographic testing, along with a biopsy confirmed diagnosis before the definitive procedure. Once a patient has been appropriately evaluated, there are three steps critical to a successful procedure: proximal tibia resection, reconstruction of the proximal tibia and knee joint with a prosthetic component, and extensor mechanism reconstruction utilizing a gastrocnemius flap to improve implant coverage and enhance the patellar tendon repair. Proximal tibia resection with prosthetic reconstruction can be associated with significant complications; however, these can be minimized with appropriate preoperative planning and a meticulous technique. Key Words: Bone tumor—Resection—Proximal tibial reconstruction—Complex total knee arthroplasty—Proximal tibial replacement.

The proximal tibia is the second most common anatomic site for primary bony sarcomas. Historically the procedure of choice for malignant bony lesions in this area was amputation (above or through the knee). This treatment modality was recommended because of the intrinsic difficulties associated with surgical limb salvage in this area as well as concerns for recurrence in the absence of wide or radical resection. However, over the past 20 years there have been significant advances in surgical techniques and adjuvant therapy that allow for limb salvage along with appropriately wide resection of primary bony sarcomas that do not alter the 5-year survival rates.

Surgical options for lesions in the proximal tibia are grouped into two primary treatment arms, limb ablative, and limb sparing. Limb ablative surgeries include amputation or rotationplasty. Limb sparing surgeries include arthrodesis with autograft or allograft or proximal tibial replacement and reconstruction with either allograft, allograft-prosthetic composite, or endoprosthesis. When comparing the efficacy and utility of these two treatment arms it is important to analyze them in four clinically relevant areas, as described by Simon. Will survival be affected by treatment choice, how do short and long-term morbidity compare, how will function of a salvaged limb compare with that of a prosthesis, and are there any psychosocial issues.

Recent orthopaedic literature has shown that limb-sparing surgery in the presence of adjuvant therapy does not increase mortality relative to ablative procedures. In fact, limb sparing surgeries have been shown to have a trend for increasing 5 year survival and decreasing recurrence rates. Morbidity is higher in both the peri-operative and long-term postoperative period for all types of limb sparing procedures. Endoprosthetic reconstruction has an early complication rate of 22% that increases to 55% with prolonged follow up. With allograft reconstructions good or excellent results are only achieved in 43% of patients which in large part is because of the high number of postoperative complications.
Individual patient factors become important when comparing salvaged limb function versus that of a prosthetic limb. The most influential seem to be activity level and age. Some patients will prefer amputation as it allows unrestricted activity and less potential for complications. Others desire limb reconstruction to obtain a less energy-requiring limb for activities of daily living and improved cosmesis.

The technical advances associated with endoprosthetic reconstruction of the proximal tibia focus on the inherent difficulties arising from distortion and resection of the local anatomy. These difficulties include variable and inadequate soft tissue coverage given the subcutaneous nature of the proximal tibia, neurovascular complications from the intimate relationship of the proximal tibia with the popliteal vessels and nerves, and reconstruction of the extensor mechanism of the knee. Historically, these problems have led to salvaged limbs with poor functional outcomes and subsequent revision amputations. This article outlines a technique for resection of proximal tibia bony sarcomas and reconstruction with an endoprosthetic component paying special attention to avoiding the aforementioned pitfalls associated with poor results.

SPECIFIC CONSIDERATIONS FOR PROXIMAL TIBIA RESECTION WITH ENDOPROSTHETIC RECONSTRUCTION

Resection of malignant proximal tibial sarcomas with endoprosthetic reconstruction does have the potential to be a dangerous procedure if performed by an inexperienced surgeon. Limb salvage procedures are fraught with complications that range from superficial infection to loss of limb or life. This is especially true in the proximal tibia, as it has been associated with higher morbidity than reconstruction of both the proximal and distal femur. Even with the current advances in soft tissue coverage of prosthetic components, infection rates remain significantly higher than primary total knee arthroplasties at 12%. This has significantly improved over the last decade when infection rates historically approached 33%. The reoperation and secondary amputation rates at 10 years still remain significant at 70% and 25%, respectively. However, the good functional outcomes in successful cases when performed by an experienced surgeon continue to justify limb salvage when possible.

Proximal tibial lesions most amenable to resection and reconstruction include low- and high-grade bone sarcomas and recurrent aggressive benign tumors associated with extensive bone destruction or recurrence (Fig. 1). These include osteosarcoma, malignant fibrous histiocytoma, Ewing's sarcoma, and giant cell tumor. Local involvement of the tumor into surrounding structures must be defined before operative intervention as well as location of previous biopsy sites. Anatomic considerations include the length of bone resection required for negative margins, extent of soft tissue involvement (specifically the patellar tendon, capsule, and peri-articular ligaments), and status of the popliteal artery trifurcation.

Relative contraindications to proximal tibial resection and endoprosthetic reconstruction include direct tumor involvement of the popliteal trifurcation, pathologic fracture, tibial resection requirement of greater than two-thirds of the tibial length, poorly located biopsy, and local or systemic sepsis. Although expandable prostheses are available, young age at diagnosis does limit reconstructive options if predicted residual growth is significant as these implants have an even higher complication rate.

PERIOPERATIVE EVALUATION

The preoperative work-up for proximal tibial lesions is similar to pathologic lesions identified throughout the musculoskeletal system. History not only provides an accurate time line for symptomatic complaints but also elicits information regarding the patient’s current level of activity and their postoperative expectations. A neurovascular history can also provide information pertaining to involvement of the popliteal structures if complaints include paresthesias, weakness, and hypoperfusion. The surgeon should also be aware of the patients overall health and ability to tolerate and rehabilitate an extensive surgical dissection and limb reconstruction.

The physical examination should not be limited to the affected limb. A comprehensive examination including assessment of all physiologic systems can aid in the detection of metastatic lesions and systemic disease. This should include lymph node palpation, lung and cardiac auscultation, abdominal palpation, including assessment of all physiologic systems can aid in the detection of metastatic lesions and systemic disease. This should include lymph node palpation, lung and cardiac auscultation, abdominal palpation, along with a focused lower extremity evaluation. Specific information relative to proximal tibial bony sarcomas include palpating distal pulses, checking sensory dermatomes in the foot and leg, motor evaluation at the knee, ankle, and toes, and visual inspection of the proximal tibia. An avascular lower extremity, insensitive foot, dysfunctional foot or ankle, and tumor penetration through the skin all may be contraindications to limb salvage procedures.

Radiographic work-up should include plain radiographs and magnetic resonance imaging (MRI) of the knee and entire tibia to assess bony and soft tissue extent of tumor involvement and to evaluate for skip...
lesions. If the distal femur or intra-articular structures are involved then extra-articular resection of the knee joint is required for sarcomas. The typical plane of resection is shown in (Fig. 2). The level of resection should be 3 to 5 cm beyond the abnormal or normal bone interface and must allow for salvage of the terminal one-third of the distal tibia. If the MRI demonstrates posterior soft tissue extension toward the popliteal vessels then biplane angiography is recommended. The anteroposterior evaluation allows visualization of the bifurcation of the popliteal artery into the anterior tibial artery and tibioperoneal trunk. The more important of these two branches is the tibioperoneal trunk as it gives rise to the posterior tibial artery that may be the predominant blood supply to the foot after wide resection of the proximal tibial tumor. The lateral angiogram is needed to demonstrate a viable plane between the posterior border of the tumor and the popliteal vessels. This plane is comprised of the popliteous and usually provides a soft tissue separation of the tumor from the neurovascular bundle.

A combination of a bone scan and chest computed tomography (CT) scan are indicated to evaluate for metastatic disease.

Preoperative laboratories should include a CBC, chemistries, urinalysis, and coagulation studies. Preoperative adjuvant therapy is dependent on the specific proximal tibia sarcoma being treated. A team approach including a medical or pediatric oncologist and radiation oncologist provides the most up to date and effective adjuvant care and can significantly increase patient survival and decrease recurrence.

A biopsy should be obtained before the definitive procedure. Ideally, the biopsy is done by the surgeon who will be performing the resection and reconstruction. Special care must be taken when performing the biopsy as a poorly placed biopsy, or one that results in formation of a large hematoma or contamination of structures required for a viable limb and functional reconstruction, may lead to the necessity of an amputation. Optimally, a core biopsy is performed in line with the incision for the definitive procedure that...
spares contamination of the anterior muscles, local nerves and vessels, patellar tendon, and knee joint.

OPERATING ROOM SETUP

The patient is placed in the supine position with the arms abducted on arm rests. An inflatable tourniquet is placed on the proximal thigh. A lateral post at the level of the proximal thigh is recommended to prevent the thigh from falling into abduction during the procedure. A bump is also secured to the bed under the calf such that when the knee is brought into full flexion the foot rests just proximal the bump to hold the knee in this flexed position. A room equipped with laminar flow is also advantageous as this has been shown to decrease intra-operative bacterial contamination.\textsuperscript{13} The surgical site is prepared with an iodophor-in-isopropyl alcohol solution and draped with Ioban drapes. This has been shown to decrease wound contamination and decrease drape lift off during surgery.\textsuperscript{11} Before inflation of the tourniquet the limb is exanguinaten by elevation. Es-

mark exanguination is not recommended as this can cause excursion of tumor cells from the primary tumor bed. A skin marker is used to outline the incision. The incision is outlined to include excision of the biopsy tract. Prophylactic antibiotics are recommended before inflation of the tourniquet and within 1 hour of the incision.

ANESTHESIA

Anesthetic options are similar to those available for all lower extremity surgical procedures. These include general, spinal or epidural, and regional anesthesia. Recent anesthetic literature has supported regional nerve blocks for improving postoperative pain control and decreasing postoperative blood loss.\textsuperscript{7} However, different anesthetic options carry different risks and benefits and each case should be managed based on an informed decision between the anesthesiologist, surgeon, and patient.
SURGICAL GUIDELINES

A successful proximal tibia reconstruction and endoprosthetic reconstruction is broken down into three fundamental steps. The first is resection of the tumor that includes placement of the incision and maintenance of the popliteal vessels and nerves. The second step is reconstruction of the proximal tibia and knee joint with a modular prosthetic component. The final step is reconstruction of a functional extensor mechanism and soft tissue coverage of the subcutaneous prosthesis.

Proximal Tibia Resection

The incision is highly dependent on the biopsy location. Ideally the biopsy is performed along the medial border of the proximal tibia that allows for a long medial incision (Fig. 3). The incision begins 5 cm proximal to the palpable medial femoral epicondyle and transverses along the medial retinaculum down the medial aspect of the leg. The incision includes wide resection of the previous biopsy scar by a minimum of 1 cm margin on all sides. The length of the incision...
depends on the size of the proximal tibia tumor but tends to end at the junction of the middle and distal one-third junction of the leg. A knife is used to incise the dermis. Subcutaneous dissection is done with electrocautery to maintain hemostasis. Thick fasciocutaneous flaps are elevated anteriorly and posteriorly to avoid skin necrosis. Palpation and blunt dissection help create an appropriate tumor free margin during this dissection.

Once thick fasciocutaneous flaps are raised, special attention is paid to the popliteal exploration (Fig. 4). The medial gastrocnemius muscle is retracted posteriorly and the medial hamstrings are released from their insertion on the proximal tibia. The soleus is then split to expose

**FIG. 5.** Intra-operative photograph (A) and sketch (B) showing the lateral exposure.
the popliteal trifurcation. The popliteus muscle tends to provide a substantial soft tissue margin between the proximal tibia tumor and the popliteal vessels. The sciatic nerve is identified and traced laterally and distally to expose and protect the common peroneal and tibial branches. The popliteal trifurcation is also explored. The anterior tibial artery is the first branch off the peroneal artery and is ligated to release the popliteal artery off the posterior aspect of the knee. The tibioperoneal trunk is also traced distally toward the posterior tibial and peroneal bifurcation. The peroneal artery is occasionally ligated if the tumor is large and extending into the lateral compartment.\textsuperscript{15}

When the medial exposure has been completed, attention is turned to the lateral leg. After the peroneal nerve has been identified and retracted, the biceps femoris tendon and lateral collateral ligament are transected 1 cm proximal to their insertion into the fibular head. The peroneal nerve is then dissected free from the lateral compartment fascia to expose its arborization in the proximal leg (Fig. 5). A substantial portion of the anterior compartment musculature is left applied to the tibia proximally to provide a wide margin. If possible, these muscles are transected proximal to their peroneal nerve innervation. The proximal fibula is then osteotomized 3 to 4 cm distal to the fibular head. Alternatively, the proximal fibula can be preserved if there is no soft tissue extension of tumor into the anterior, lateral, or lateral aspect of the posterior compartments. In this case, the plane of resection occurs through the proximal tibiofibular joint.

Once the nerves and vessels have been identified and protected the knee arthrotomy and capsular incisions are performed. The arthrotomy is done with a transverse incision starting at the postero-medial aspect of the knee joint and carrying anteriorly toward the inferior border of the patella. Once the arthrotomy is performed, the medial meniscus and crucial ligaments are observed for possible contamination of tumor into the joint. If there is no evidence of tumor within the joint an intra-articular resection is performed. If there is any evidence of intra-articular contamination (hemarthrosis or direct extension) then an extra-articular resection of the distal femur is recommended. The medial collateral ligament is transected along with the medial capsule. The patellar tendon is transected 1 to 2 cm proximal to its insertion on the tibial tubercle. The capsular incision is finished by carrying it circumferentially around the anterior and lateral aspects of the knee. As the lateral knee is approached, the geniculate vessels are identified and ligated. Once the medial, anterior, and lateral capsular incision is performed, the cruciate ligaments are easily visualized with the knee in the flexed position. These are sectioned close to their femoral attachments. This exposes the posterior capsule that is incised under direct visualization taking special care to avoid the mobilized popliteal vessels and nerves.

Once the proximal tibia has been exposed distally to a tumor free margin an osteotomy is performed 3 to 5 cm distal to the demarcation of most distal marrow involvement (measured preoperatively on the MRI). The proximal tibia is then removed en-bloc.

Reconstruction of the Proximal Tibia and Knee Joint

Once the proximal tibia is excised its length is measured. A modular component is then created that mimics the length of the current bone void. If the resection was done in an intra-articular fashion distal femoral bone cuts are performed with the appropriate cutting jigs. A hinged endoprosthetic component is then assembled with femoral and tibial intramedullary stems. The intramedullary canals are prepared. The component is trialed to confirm appropriate soft tissue tension and the bone ends are copiously irrigated. Once the bone ends are dry third generation cementing techniques are used to affix the endoprosthetic component to the distal femur and proximal tibia. Depending on surgeon preference, the femoral and tibial stems can be placed in cemented or uncemented fashion. During cementation, the knee is extended with the foot in the anatomic position such that the patella is in vertical alignment with the second metatarsal. The patella is not routinely resurfaced unless associated with advanced degenerative arthritis. An intraopera-
Extensor Mechanism Reconstruction and Soft Tissue Coverage

A four-stranded Krackow stitch with two #2-fiber wires is then placed in the patellar tendon. This is tied down to the holes in the proximal tibial prosthesis. The tendon is reattached with the knee in full extension in an effort to decrease the postoperative extension lag. A medial gastrocnemius flap is then mobilized by dividing the medial head of the gastrocnemius off the soleus with some of its distal attachment to the Achilles tendon (Fig. 7). The flap is rotated medially with its blood supply maintained from the medial sural artery. It is then sewn to the remaining fascia of the anterior compartment to cover the entirety of the prosthesis (Fig. 8). If the length of the prosthesis does
FIG. 8. Intra-operative photograph (A) and sketch (B) showing the completed extensor mechanism reconstruction with medial gastrocnemius flap.
not allow for complete coverage with the rotated flap, the medial border of the soleus can be advanced antero-medially and attached to the flap to extend its length. The length of the gastrocnemius flap can also be increased by transversely sectioning the deep fascia. The soleus muscle is also sewn to the anterior compartment muscles distally to cover the exposed tibia.

The medial and lateral capsular structures are advanced distally and tenodesed to the superior borders of the rotated gastrocnemius flap. The proper tension for this closure is obtained by allowing 30 to 40 degrees of flexion on the table without stress on the repair. The medial hamstrings are reattached to the rotated gastrocnemius flap. Subfascial drains are placed which exit in-line with the incision. The skin is then closed primarily if possible. If skin closure is under inappropriate tension a split thickness skin graft can be used. The need for skin grafting is, however, rarely necessary in the experience of the senior author. Postoperative radiographs are shown in (Fig. 9).

**POSTOPERATIVE CARE**

A long-leg bulky Jones dressing is applied in the operating room with the leg splinted in full extension before emergence from anesthesia. The drain is discontinued at 48 hours. This dressing is changed 2 weeks
postoperatively when the wound is checked. Sutures are removed at this time if the wound is sealed and the patient did not undergo preoperative chemo or radiation therapy (in which case they are removed 4 weeks postoperatively or when the wound is sealed). The patient is encouraged to begin physical therapy on postoperative day 1 with full weight bearing on the operative extremity. When the dressing is changed at 2 weeks a hinged knee brace is applied, locked in full extension. Six weeks postoperatively the brace is adjusted to allow motion from 0 to 30 degrees of flexion and advanced 10 degrees per week until full extension is obtained.

CONCLUSION

Improvements in surgical techniques over the past 10 to 20 years have significantly improved the outcome of endoprosthetic reconstruction after proximal tibia resection for tumors. The improved outcome and equivalent recurrence and survival rates have promoted limb salvage surgery over the less cosmetically appealing limb ablative procedures. Although the concepts associated with proximal tibia resection are relatively uniform among surgeons, reconstruction of the proximal tibia and knee joint and extensor mechanism reconstruction with soft tissue coverage vary from surgeon to surgeon. A proximal tibia osteoarticular allograft, as opposed to an endoprosthesis, can be used to reconstruct the proximal tibia after resection. This cadaveric reconstruction has been shown to have slightly inferior outcomes and 5-year survival rates. Allograft-prosthetic composites have also been used to reconstruct the knee joint. Infection rates and failure of the extensor mechanism are highest with this type of reconstruction at 23% and 23%, respectively.

Extensor mechanism reconstruction has also been described without a gastrocnemius flap. In this technique, the patellar tendon is attached directly to the prosthesis and the skin is closed primarily. As described by Lackman et al., extension lag with this technique at 3 years is 7.5 degrees and the reoperation rate is 10%. In the experience of the senior author, reconstruction with a proximal tibial endoprosthesis utilizing a gastrocnemius muscle flap has provided the most reliable and predictable results when compared with the other reconstructive options.

REFERENCES

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES