Tips and tricks of limb salvage: Proximal tibia

Ajay Puri

Abstract

Due to its anatomical location, the upper end of the tibia poses unique problems while attempting limb salvage and appropriate reconstruction. This article attempts to highlight a few of the key steps, pearls and pitfalls while attempting this challenging procedure.

Key words: Arthrodesis, megaprosthesis, osteosarcoma, proximal tibia

Introduction

The proximal tibia is the second most common site for primary malignant bone tumors.[1] The last few decades have seen rapid strides in limb function preserving surgery alternatives because local control in these lesions is becoming the norm without compromising on overall disease survival. The advent of better imaging modalities, more effective chemotherapy, improved radiotherapy techniques, a better understanding of anatomy with continuous refinement in surgical techniques and advances in prosthesis design and materials have all played a part in achieving this goal.

Though the number of limb salvage surgeries undertaken for malignant bone tumors of the extremity has increased, the principles that govern surgical resection of bone tumors have remained unchanged. The surgeon must ensure adequate resection of involved bone and soft tissue so as to minimize the chance of local recurrence. If after achieving this goal, he is still able to preserve adequate function of the limb after reconstruction, then the patient is a suitable candidate for limb salvage. At no stage must adequate disease clearance be compromised in an attempt to achieve limb salvage. Balancing these two opposing goals can often be a Herculean challenge, especially in patients with large tumors, and it is not uncommon for patients with limb tumors in developing countries to have an amputation for local control. The techniques for limb salvage in the proximal tibia include endoprosthetic replacement, reconstruction with an osteochondral allograft or resection followed by arthrodesis.[1,2]

Megaprostheses form the mainstay in limb salvage surgery for reconstruction after tumor resection and have demonstrated excellent functional results.[1,3] Though international prostheses are routinely available, cost constraints preclude their use in a large majority of patients in the developing world. Hence low cost, locally manufactured prosthesis have remained the workhorse for surgeons in these nations for prosthetic reconstructions after limb salvage. Though these prostheses (usually available at a cost between US $1200-1800) did have initial problems with early failure, the advent of better manufacturing techniques and increasing surgeon involvement in design development have helped create a durable prosthesis option at more affordable costs over the past decade.[4] However, the limited availability of a "low cost" expandable prosthesis still poses constraints in reconstruction options for growing children. Prior to surgery, the surgeon must familiarize himself with the instrumentation technique specific to the prosthesis being used.

Surgical Tricks and Tips

Endoprosthetic replacement

Adequate preoperative planning helps the surgeon decide the length and extent of resection (the maximum tumor dimensions may be either intramedullary, periosteal or in terms of the associated soft tissue component). Both, the magnetic resonance imaging (MRI) and the plain radiograph need to be carefully evaluated as often the periosteal reaction may be better appreciated on the plain radiograph. A 2-3 cm marrow margin as calculated on the T1-weighted MRI image is considered an adequate resection margin [Figure 1A]. Resection parameters are planned

Department of Orthopaedic Oncology, Tata Memorial Hospital, Parel, Mumbai, Maharashtra, India

Address for correspondence: Prof. Ajay Puri,
Room No: 45, Tata Memorial Hospital, E. Borges Road,
Parel, Mumbai - 400 012, Maharashtra, India.
E-mail: docpuri@gmail.com

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based on prechemotherapy imaging unless fresh imaging reveals an increase in the extent of disease.

A tourniquet is preferred with care being taken to exsanguinate the limb by gravity and not by using a compression bandage. The anteromedial approach extending from the distal femur to the anteromedial tibia is the preferred approach as it allows for an excellent exposure of the vessels, fibula and medial gastrocnemius muscle [Figure 1B].

The surgeon must evaluate carefully to see if there is tumor extension into the proximal tibio fibular joint. Though it is not routine practice to excise the head of the fibula when excising proximal tibial tumors, in case of disease extension into the proximal tibio fibular joint the head of the fibula is excised en bloc with the proximal tibia [Figure 1C].[1,5] Prior to this the lateral popliteal nerve needs to be carefully dissected free to prevent injury to it.

Figure 1A: Plain radiographs anteroposterior (a) and lateral (b) views and T1-weighted magnetic resonance imaging image (c) showing an osteosarcoma of the upper tibia showing the planned resection length (arrow)

Figure 1C: Postoperative radiograph of the case shown in Figure 1A with showing prosthesis *in situ*. Note that the proximal fibula has been excised too

Though infrequent, the surgeon must be aware that the possibility of intraarticular extension into the knee joint exists. In such a case, an en bloc excision of the distal femur along with a slice of the patella to avoid opening the joint is carried out along with a resection of the proximal tibia.[6] The subsequent defect is then reconstructed with a "composite" prosthesis that includes a distal femoral and a proximal tibial component [Figure 2]. Using a patellar component in such cases is a matter of individual choice though most surgeons would choose not to resurface the patella.

The upper end of the tibia poses unique problems.[1] The complex vascular anatomy in the popliteal fossa adds to the challenges. A large posterior soft tissue component often causes tethering of the vessels and can necessitate delicate dissection to ensure that the posterior tibial vessels are dissected free of the tumor. Frequently, the anterior tibial vessels may need to be ligated as they pass from the posterior compartment anteriorly [Figure 3]. The surgeon must ensure that the continuity of the posterior tibial vessels is maintained and he is not inadvertently ligating the tethered popliteal/posterior tibial vessels at the point where the anterior tibial branches out to pass over the interosseous membrane.


Figure 1B: Clinical photograph showing healed postoperative scar of the anteromedial approach extending from the distal femur to the anteromedial tibia

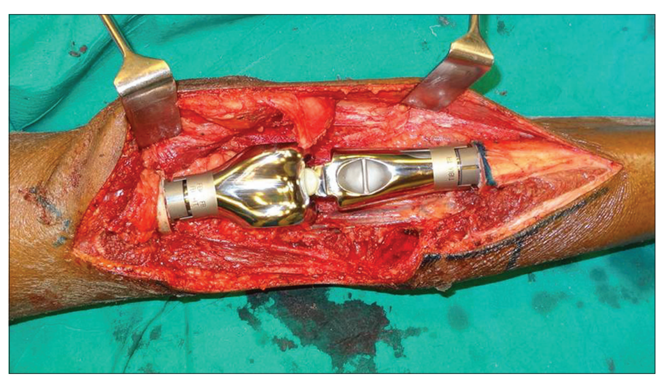
Figure 2: Peroperative photograph showing a "composite" prosthesis that includes a distal femoral and a proximal tibial component

The patellar tendon is sectioned proximal to its attachment on the tibia during resection. Reattaching the extensor apparatus to the prosthesis to enable active extension is mandatory. In addition, the majority of the prosthesis lies subcutaneously with little overlying muscle cover and this can increase the chance of infection, in case there is a delay in wound healing.[3] Most proximal tibial prosthesis have a hook or holes on the anterior surface of the prosthesis to which the patellar tendon can be anchored. The patellar tendon is sutured onto this with the help of no: 2 Ethibond. A bone plug (shaped from the excised cancellous bone of the distal femur) is wedged under this hook prior to attaching the patellar tendon [Figure 3b]. It is hoped that the attached patellar tendon would eventually have a permanent biological attachment to this "wedged" bone plug thus providing a strong lever arm for knee extension.

Most surgeons would also use an elective medial gastrocnemius flap in proximal tibial resections.[1,3,7] The flap is preferably dissected out after resecting the proximal tibia but prior to implanting the prosthesis. This is technically easier than after the prosthesis is implanted. Care must be taken not to carry the dissection too far proximally to avoid injury to the vascular pedicle of the medial gastrocnemius muscle (the medial sural artery, the main pedicle of the medial gastrocnemius muscle, arises off the popliteal artery 1-2 cm below the joint line). The muscle flap is brought forward anteriorly to cover the prosthesis [Figure 3c]. It serves the dual purpose of providing a layer of muscle cover to the subcutaneous prosthesis and also providing a biological anchorage to the patellar tendon which is sutured to it with absorbable sutures. In certain situations where excess skin may need to be excised at the time of resection (because of an improper biopsy), the gastrocnemius muscle flap also serves as a good bed for a split thickness graft if primary skin closure is not possible.

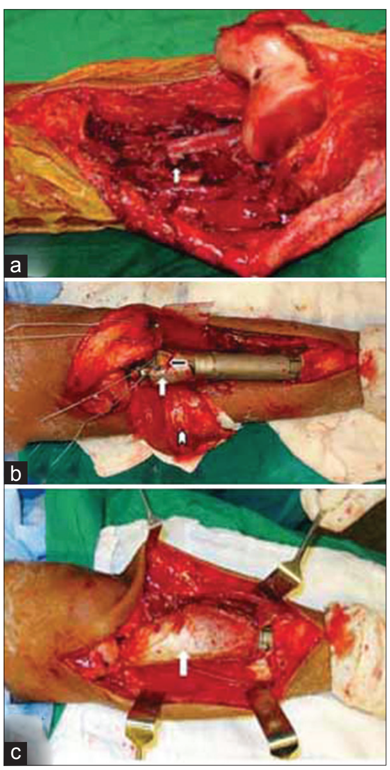

Figure 3: Peroperative photographs showing (a) Ligated stump of anterior tibial artery (arrow) with continuity of the posterior tibial vessels (b) Patellar tendon being anchored to hook on prosthesis. Bone plug wedged under the hook (black arrow). Polypropylene mesh (white arrow) being wrapped around the proximal tibial prosthesis. Harvested medial gastrocnemius muscle flap (arrowhead) (c) Medial gastrocnemius muscle flap brought forward anteriorly to cover the prosthesis

Recently, the author has started using a thin sleeve of polypropylene mesh (Prolene™ – Johnson and Johnson) tightly wrapped circumferentially around the proximal tibial prosthesis at the site of patellar tendon anchorage [Figure 4a]. The patellar tendon and the medial gastrocnemius flap are additionally sutured to this mesh. It is hoped that the resultant circumferential fibrosis around the proximal part of the prosthesis would serve as a mechanical pulley subsequently aiding and enhancing the extensor mechanism of the knee.

Aseptic loosening is a major cause of long term prosthesis failure.[3] Marrow reamings and chips of cancellous bone (from the excised cancellous bone of the distal femur) are laid at the bone prosthesis junction in the hope of providing a biological purse string by facilitating bony ingrowth at the bone prosthesis junction. This can help promote longevity of the construct by decreasing the incidence of aseptic loosening.

As mentioned earlier, the limited availability of a "low cost" expandable prosthesis still poses constraints in reconstruction options for growing children. While in very young patients rotationplasty remains an often

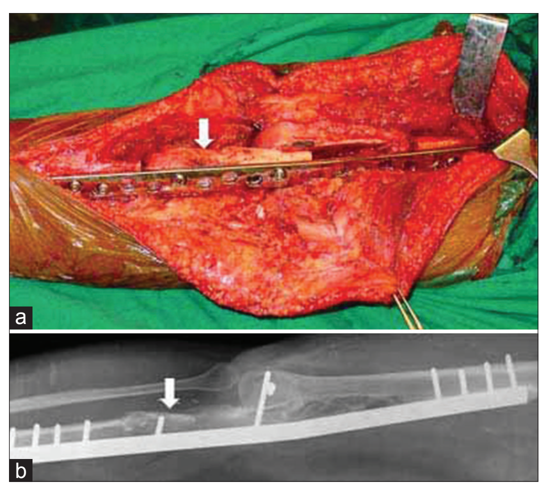

Figure 4: Arthrodesis using a hemicortical autograft from the distal femur (white arrow) turned down to bridge the resultant gap after proximal tibial excision

used alternative, in patients nearing skeletal maturity the anticipated limb length discrepancy can be partially offset by lengthening the operated limb by 1.5-2 cm at index surgery (reconstruct with a prosthesis that is longer than the excised segment). Lengthening beyond 2 cm increases the risk of neurovascular compromise. Occasionally after lengthening, the limb may need to be immobilized in 15-20° of flexion in the immediate postoperative period to relax the stretched neurovascular structures. Gradual straightening of the limb is accomplished over a period of 7 days.

Following surgery, supervised rehabilitation is critical to gain optimum knee function. The patients are mobilized full weight bearing immediately (the author uses cemented prosthesis) but the knee is immobilized in a back knee splint for a period of 6 weeks. Flexion to 30° is permitted 6 weeks after surgery progressing to 90° over an additional 6 weeks. Active knee extension exercises are initiated between 8 and 10 weeks after surgery.

Resection arthrodesis

Though arthrodesis of the knee may not be a favored option after resection because of the functional limitations, it is still a popular alternative in developing countries. It is difficult to argue against the durability of this robust and inexpensive reconstruction, especially after resection of large benign lesions where the patient is expected to have a normal life expectancy. The physical demands placed on a reconstruction in patients whose livelihood depends on hard manual labor can be a deterrent to the use of prosthesis. The potential costs of possible future revision surgeries often makes patients opt for arthrodesis as the primary reconstruction modality. Another situation where an arthrodesis may be a possible option is in large tumors when a considerable amount of quadriceps muscle is sacrificed in order to obtain adequate oncologic clearance. A mobile joint may not be the best reconstruction modality in this scenario.

Traditionally, autografts and allografts have been used to bridge the defect in order to achieve an arthrodesis. The autograft can be in the form of a vascularized fibula or can also be a longitudinal hemicortical resection of the distal femur turned down to bridge the resultant gap after proximal tibial excision [Figure 4b].

In the developing world strut allografts as a means of biological reconstruction are limited by their availability as very few centers have access to bone bank facilities. Cultural barriers to organ donation also restrict the availability of strut allografts even in centers with tissue banking facilities. Even when available, strut allografts alone have been shown to have a high incidence of failure and when used for an arthrodesis should ideally be combined with a vascularized fibula nestling in a trough cut in the allograft.[8]

Besides conventional means of arthrodesis, it is possible to use cement spacers coupled with inexpensive internal fixation devices (stacked Kuntscher nails combined with a plate for rotational stability) as a primary reconstruction option for limb salvage.[2] Care should be taken to ensure that a minimum of 8-10 cm of the nail is in the intramedullary canal on either side in both femur and tibia to provide adequate stability and strength of the construct.[9] This enhances the mechanical properties thus reducing the incidence of implant failure. Besides being cost effective, cement spacers provide other advantages as well. The operating time is shorter compared to methods using biological reconstructs which require either harvesting an auto graft or shaping an allograft to ensure optimal fit. The necessity of a specialized tissue bank for procuring allografts is not a constraint. Unlike biological reconstructions, cement spacers are unaffected by adjuvant treatment modalities. The rehabilitation schedule does not depend on evidence of graft incorporation or "hypertrophy" of the graft and patients are ambulant with immediate weight-bearing on a stable limb. In cases with fungating, infected tumors at presentation there is an obvious reluctance to use either prosthesis or grafts. Here antibiotic impregnated cement spacers provide an alternative to an amputation. A potentially exciting addition could be the incorporation of antineoplastic drugs in the bone cement to enhance local drug delivery in large tumors. Healey has shown that polymethylmethacrylate cement mixed with doxorubicin retained adequate strength and sufficient amounts of the drug eluted to have potential biologic activity.[10]

It is also possible to subsequently successfully carry out a secondary revision of the cement spacer to a prosthesis or biological arthrodesis if the need arises or the patient desires it.[9]

Conclusion

To summarize, the surgeon must decide with consultation of the patient what is the best surgical procedure for that individual and he is then responsible for achieving adequate margins and reconstructing the limb if limb salvage is chosen. Striking the right balance between adequate resection while yet retaining or reconstructing tissue for acceptable function and cosmesis is a difficult task. Though challenging and at times unduly demanding, the satisfaction achieved by both, patient and surgeon after successful limb salvage is unparalleled and is the elixir that drives oncosurgeons to continuously refine their skills and evolve better, more robust methods of reconstruction.

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