Extremity reconstruction in sarcomas

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ABSTRACT

In the last few decades significant advances have occurred in the diagnosis and therapy of bone and soft tissue sarcomas of the extremities, which has made it possible to avoid amputations and conserve the limb in many cases. But careful case selection has to be done and consideration has to be given to the influence of adjuvant modalities needed in the management. This article reviews the various aspects of limb salvage in extremity sarcomas including the methods of reconstruction in detail. Problems of reconstruction in a growing child is also dealt with separately.

KEY WORDS
Bone tumors, soft tissue sarcoma, limb salvage

“Amputation is the most merciful of surgeries when indicated but the meanest option when other alternatives exist”.

WHEN IS LIMB SALVAGE RECOMMENDED?

Limb salvage is recommended only if:
1. The ability to achieve adequate margins is not compromised. If the surgeon is unable to achieve adequate margins in his endeavour to salvage the limb then an amputation is preferred.
2. The salvaged limb will provide function superior to that offered by a prosthetic limb after an amputation. A non sensate salvaged limb with inadequate motors defeats the very purpose of limb salvage which aims at improving the patient’s quality of life.

WHAT ARE THE BARRIERS TO LIMB SALVAGE?

Barriers to limb salvage include poorly placed biopsy incisions, major vascular involvement and encasement of a major motor nerve, pre operative infection and inadequate motors after resection. These adverse factors though barriers are not absolute contraindications. Advances in microsurgical techniques offer the ability to transfer motors, graft nerves and vessels and provide adequate soft tissue even after extensive resections of overlying skin and muscles.
HOW DOES THE USE OF ADDITIONAL ADJUVANT MODALITIES IMPACT ON LIMB SALVAGE?

Though surgical resection remains the mainstay of treatment in musculoskeletal tumors it is uncommon for a patient with a high grade sarcoma to be treated by surgery alone. Adjuvant modalities like chemotherapy and radiotherapy play an essential part in the integrated management of these patients. A majority of bone tumors would receive chemotherapy while some like Ewing’s sarcoma would benefit from additional radiotherapy. Most extremity soft tissue sarcomas too would receive chemotherapy and radiotherapy. Continuous interaction and coordination between the various treating disciplines is important in order to provide the different treatment modalities in the most optimum sequence at appropriate times. Surgery must be planned in such a manner so as not to unduly disrupt the delivery of these adjuvant modalities. Problems in wound healing can result in a delay in the post operative delivery of these modalities, which could compromise both local and distant disease control.

Both chemotherapy and radiotherapy can have a deleterious effect as far as surgery is concerned. Patients receiving chemotherapy are often immuno compromised resulting in an increased susceptibility to post operative infection. Radiotherapy if administered preoperatively has been shown to increase the incidence of wound complications often necessitating the use of local or distant flaps primarily in an attempt to forestall these complications. Post operative radiation too can result in radiation induced ulcers and wound dehiscence often exposing underlying bone (Figure 1), neurovascular structures and metallic prosthesis.

WHAT ARE THE LIMITATIONS OF LIMB SALVAGE?

Though properly indicated and executed limb salvage offers the advantage of better function and psychological benefits resulting in an overall improvement in quality of life it does have its drawbacks. It requires a well coordinated experienced multidisciplinary team. There is evidence to show that patients with sarcomas managed in specialty centres do better. The cost of treatment can be expensive and the post operative rehabilitation is prolonged often requiring increased inpatient hospital care. Limb salvage procedures have a higher complication rate and patients and their families need to be counseled regarding the potential setbacks that may occur in the course of their road to recovery.

WHAT ARE THE VARIOUS OPTIONS FOR RECONSTRUCTION AFTER RESECTION?

Soft tissue sarcomas

A vast majority of these patients would require radiotherapy (either brachytherapy and / or external radiotherapy). Though there are proponents for both pre and post operative radiotherapy, most centres in India prefer post op radiotherapy. Split skin grafts even if possible fare poorly when subjected to radiation and hence it is preferable to have a robust flap for soft tissue cover in case primary closure is not possible following resection. Incisions closed under tension are also liable to break down during or after radiotherapy leading to prolonged delays in wound healing with a detrimental cascading effect on the delivery of adjuvant treatment modalities. In case the underlying bone or metallic prosthesis is exposed, a flap is mandatory in order to cover it and enable early wound healing and rehabilitation. Thus a relaxed, tension free, robust soft tissue cover is the cornerstone to ensure that heroic resections are not doomed to disaster in a milieu that is otherwise detrimental to wound healing.

Flaps can be local or distant (Figure 2), pedicled or free, depending on the anatomic area affected and the condition of the surrounding tissues whether it has been violated by prior surgery or not. It is preferable to start raising the flap only after primary resection is complete. An intraoperative frozen section may reveal compromised margins often mandating the removal of additional tissue. Thus if the flap has been harvested simultaneously during
Reconstruction in sarcomas

Occasionally the plastic surgeon may be called on to transfer muscles or tendons when certain motor groups have been resected in an attempt to achieve adequate margins. Sarcomas as a rule tend to displace vessels and nerves and do not infiltrate them primarily. Occasionally the nerve and/or vessel may be encased by a large tumor or infiltrated in the event of prior surgery. Resection of the involved vessel or nerve would require appropriate reconstruction.

Bone tumors

Reconstruction after excision of bone tumors requires restoration of both, skeletal and soft tissue elements.

Most bone sarcomas occur in the metaphyseal portion of the bone. The articular cartilage serves as a barrier to extension of the tumor and the joint itself is rarely involved but in order to achieve adequate margins, resection usually involves the articulating or joint surface. At the meta diaphyseal end a marrow margin of 3 cms as evaluated on the T1 weighted MRI image is usually considered adequate. The gap remaining needs reconstruction with either metal or bone. Of the various options available, a metallic prosthesis, which spans the gap and allows for movement of the joint, is the most attractive proposition [Figure 3]. As these joints replace large segments of bone they are called megaprostheses. They provide an immediate return to function and unlike bone are not affected by ongoing adjuvant chemotherapy and radiotherapy. They thus form the mainstay in limb salvage surgery for reconstruction after tumor resection.

The disadvantage of a metallic prosthesis is that like any other mechanical device that is subjected to repeated loading it is prone to fatigue failures and loosening in the long term. Developments in biomechanical engineering and material sciences have reduced the incidence of such failures and recent studies have shown impressive survival data for these mega prostheses.[5]

Prosthetic reconstructions in certain areas like the proximal tibia are more complex. The main problem is the loss of the extensor mechanism attachment at the tibial tubercle and the subcutaneous nature of the replaced bone. Most surgeons routinely cover the prosthesis with a gastrocnemius muscle flap which serves the dual purpose of providing soft tissue coverage to the prosthesis and also allowing a more biological anchorage for the patella tendon which is attached to the muscle flap instead of the prosthesis.

In cases of whole bone involvement megaprostheses can be used to replace the entire bone. Due to anatomical and functional constraints this is usually only done in the proximal part of the extremity i.e. the humerus and the femur.[6,7]

Bone in the form of fibula autografts (non vascularised / vascularised) [Figure 4] or banked allografts can also be used.
used to reconstruct the defects subsequent to resections involving the articular surface. Osteochondral allografts were used in an attempt to recreate a mobile joint but long term data has not been very encouraging.[8] Conventional strut allografts and fibula autografts have the disadvantage of being unable to provide a mobile articulating surface. Thus spanning the defect with these would result in an arthrodesis and inability to move that particular joint. Though use of these grafts offer a cheaper, more biological and durable option, the resultant disability is often not acceptable to patients, a majority of who prefer to opt for a megaprosthesis.

For tumors that involve the diaphyseal portion of a bone, an intercalary resection and reconstruction can be performed that saves the joints at either end. In these cases the excised segment of bone can be replaced with either a metallic diaphyseal prosthesis or bone in the form of a strut allograft or fibular autograft.[9] While it was initially hoped that massive allografts would become fully incorporated into the host, retrieval data shows that only a small percentage of the allograft actually becomes revascularized while the rest remains necrotic. Rather than a biologic replacement for the excised bone segment the allograft functions as a biologic spacer.[10] Allografts have their share of complications too which include infection, nonunion and late fractures.

A single vascularized fibula is often not strong enough to withstand the loading after reconstruction of large defects especially in the lower extremity and fractures are not uncommon. In an attempt to improve the incorporation of allografts while providing additional structural stability to the vascularised fibula, Capanna has advocated using a combination of a strut allograft with a vascularized fibula autograft.[11] In the entire series of 90 patients with an average resection length of 16 cm (range, 7-26 cm) and an average follow-up of 9 years (range, 3-17 years), 25 had a complication requiring a surgical revision (27.7%) with an average of a single operation needing to be performed. Failure of the reconstructive technique occurred in six patients (6.5%), four because of an infection and two because of a fracture of the combined allograft.

Sequential controlled bone transportation as proposed by Ilizarov has also been used to fill defects created after skeletal resection.[12] Defects are usually large and the process of bone regeneration can be a long drawn affair. The presence of multiple external pins and wires for extensive periods required by this method can be a problem in patients who are immuno compromised because of chemotherapy and therefore susceptible to pin tract infections. The quality of the bone regenerate may also be altered because of adjuvant therapies.

Recently there has been a lot of interest in using the patients own tumor bone and replacing it after it has been sterilized. Methods of sterilization described have included the use of autoclaving,[13] microwave, pasteurizing, liquid nitrogen and radiotherapy[14] (extracorporeal radiotherapy) [Figure 5]. The principle is the same; the tumor bearing bone is excised as usual, all soft tissues and macroscopic tumor removed and the remaining bone sterilized by any of the above methods before being reimplanted. Although the bone is dead the advantage is that it functions as a “size matched“ allograft. An essential pre-requisite is that the bone should initially not be damaged significantly by the tumor otherwise it would become too weak to use once sterilized. The problems inherent with allograft

![Image](https://example.com/image1.png)

**Figure 4:** A) Ewing’s sarcoma in diaphyseal area of femur, B) Excision and reconstruction with a vascularised fibula, C) Hypertrophy of the vascularised fibula on subsequent follow up

![Image](https://example.com/image2.png)

**Figure 5:** A) Ewing’s sarcoma in diaphyseal area of humerus, B) Post excision specimen to be sent for extracorporeal radiotherapy, C) Post operative radiograph, D) Osteotomy sites uniting on follow up, E) Defect after excision (white arrow), F) Host bone reimplanted after extracorporeal radiotherapy
usage remain and hence it too can be combined with a vascularised graft.\cite{15} The technique is relatively time consuming but cheap to use. As the patient's own bone is used it avoids the logistic issues involved in allograft procurement and the fear of disease transmission.

Other reconstructive procedures such as rotationplasty, fibula pro tibia and clavicula pro humero are useful in specific anatomic areas.

Rotationplasty is essentially an intercalary limb resection preserving the continuity of the neurovascular bundle\cite{16} [Figure 6]. The most common site where rotationplasty is used is for tumors of the distal femur and proximal tibia. Patients undergo an en bloc excision of the distal femur and proximal tibia including skin and all surrounding soft tissues. The limb continuity is then re-established by fusing the tibia with the proximal femoral remnant after 180° external limb rotation. The vessel can either be dissected out or divided and reanastomosed but the sciatic nerve has to be carefully preserved and retained. In case the vessels are not divided but dissected out, subsequent additional vessel length after limb shortening is accommodated for by carefully looping the vessels so as to avoid stasis. Limb rotation is necessary as otherwise the foot would end up pointing forwards. Once rotated however, the ankle now becomes the knee and the foot becomes a useful attachment for a below knee prosthesis. Ankle movements simulate knee movements and the patient has the equivalent of a functioning below-knee amputation rather than a high above knee one. A major advantage is that the sole being the normal weight bearing area there is no phantom pain. The stump can be left longer in children to account for subsequent growth of the contra lateral limb so that the opposite knee and the repositioned rotated ankle of the operated limb would lie at the same level at skeletal maturity.

As skin, quadriceps and the vessel can be sacrificed to provide a wider margin this procedure is also applicable in cases with extensive involvement of the quadriceps or where skin has undergone prior radiation. It is also used to salvage cases with uncontrolled infection following a prosthetic replacement.

Resections involving the diaphyseal area of the tibia can be reconstructed using the fibula pro tibia procedure. Following adequate resection of the tibia the fibula is osteotomised proximally and distally at the appropriate level. It is then transposed medially keeping the entire soft tissue attachments intact and fixed proximally and distally to the residual tibia. This now functions as a vascularised graft resulting in rapid union with subsequent hypertrophy when subject to loading. A similar concept is applied in the upper limb with the distal ulna being transposed to fill the defect left after resection of the distal radius.

Transposition of the clavicle in order to replace the humerus (clavicula pro humero) originally used in phocomelia is also useful as a biological reconstruction after the resection of malignant bone tumors involving the proximal humerus.\cite{17} The clavicle is cut at the sternoclavicular joint and with its periosteum intact rotated around the acromioclavicular joint. The medial end is shifted downward to fuse with the residual humerus. In patients with a more extensive resection of the proximal humerus, the clavicle alone may not be adequate to cover the defect and a vascularized fibula graft to supplement the length in extensive bone defects has reported good functional results.\cite{18}

**RECONSTRUCTIONS IN GROWING CHILDREN - PROBLEMS AND POSSIBLE SOLUTIONS**

Children, because of the dynamic nature of growing bones pose a unique challenge.\cite{19} They have a narrow medullary cavity (which limits the size of intramedullary prosthetic stems), continually remodeling bone and pose a greater functional demand on their reconstructions. The issue of ultimate limb length discrepancy also influences the choice of reconstruction especially in the lower limb. Vascularised epiphyseal transfers (proximal fibular epiphysis, iliac crest, lateral scapular crest) may provide...
a solution to this complex problem.[20] Procedures like clavicle pro humero in which the intact lateral clavicle epiphysis may make some contribution to residual skeletal growth may help limit the limb length discrepancy at skeletal maturity. A properly planned rotationplasty can help ensure that the opposite knee and the repositioned rotated ankle of the operated limb lie at the same level at skeletal maturity thus limiting the cosmetic deformity after prosthetic fitting.

An expandable prosthesis is another solution to the problem of limb length discrepancy that would result in young children offered salvage with a megaprosthesis. The newer generation expandable prostheses even permit expansion with non-invasive techniques by allowing graduated extension when subjected to a controlled external magnetic field.[21]

CONCLUSION

The surgeon must decide with 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. Limb salvage entails a well orchestrated effort involving various specialties and better outcomes are likely to be achieved with centralization of expertise at regional centres so that surgeons and their teams can offer a full range of surgical options to their patients, based upon experience and knowledge. Striking the right balance between adequate resection while yet retaining or reconstructing tissue for acceptable function and cosmesis is a difficult task and complications are not uncommon but the satisfaction achieved by both, patient and surgeon after a successful Limb salvage is unparalleled and is the elixir that drives oncology surgeons to scale new heights.

REFERENCES


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