FLOW THROUGH FIBULA FLAP FOR UPPER LIMB RECONSTRUCTION IN SARCOMA PATIENTS

Dissertation submitted to partial fulfillment of the requirements for the degree of

M.Ch. (Plastic & Reconstructive Surgery) – Branch III

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

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CERTIFICATE

This is to certify that the dissertation entitled "**FLOW THROUGH FREE FIBULA FLAP FOR UPPER LIMB RECONSTRUCTION IN SARCOMA PATIENTS**" is a bonafide work done **DR. K.A. BALASUNDARAM**, *post graduate (2011-2014) in the Department of Plastic, Reconstructive & Faciomaxillary Surgery, Madras Medical College & Rajiv Gandhi Government General Hospital, Chennai – 03*, in partial fulfillment of the University rules and regulations for award of **Master of Chirurgiae**, ***Plastic & Reconstructive Surgery (branch III)*** degree under my guidance and supervision during the academic year 2011-2014.

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DECLARATION

I solemnly declare that this dissertation "**FLOW THROUGH FREE FIBULA FLAP FOR UPPER LIMB RECONSTRUCTION IN SARCOMA PATIENTS**" was done by me in the Department of Plastic, Reconstructive & Faciomaxillary Surgery, Madras Medical College & Rajiv Gandhi Government General Hospital, Chennai-03 between 2011 and 2013.

This dissertation is submitted to **THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY, GUINDY, CHENNAI-32** in partial fulfilment of the university requirements for the award of degree of **M.Ch. PLASTIC & RECONTRUCTIVE SURGERY**.

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CONTENTS

INTRODUCTION

SOFT TISSUE SARCOMAS (STS) are rare malignant tumors arising from extraskeletal mesenchymal tissues. They are less than 1% of all newly diagnosed malignant tumors in the United States. Of these only 25% occur at the upper extremity.[1]

STS of the extremities used to be treated with amputation in as much as half of the patients. Nowadays limb-sparing surgery , without any compromise in local control or survival rates, is performed.[2] Advances in tumour biology understanding, improved chemotherapy and radiotherapy(neoadjuvant or adjuvant in post op treatment), ability of surgical oncologists to excise the tumour with a good margin(principle of excision without seeing the tumour) and advances in plastic surgical expertise where there is a technique available to reconstruct any composite defect of the axial vessels of the hand compromising its vitality, have all paved the way for limb salvage surgery. Oncological resections, especially in the forearm sarcomas have resulted in complex composite defects with loss of variable amount of bone, muscle, vessels , nerves and skin.

These defects pose challenging options for any reconstructive surgeon. To envisage vitality and function of the hand, as a part of Limb

Preservation Surgery(LPS), it requires a vessel conduit to bridge the defect in the vascular continuity and at the same time it should also provide skeletal stability, muscle and tendon continuity with or without recipient nerve anastomosis and finally the skin cover.

All these requirements are effectively addressed by the flow through fibula osteocutaneous flap, where the peroneal artery restores the vascular deficit by acting as the conduit; the fibula provides the skeletal continuity (sometimes as a single bone forearm reconstruction); the peroneus longus harvested on an independant peroneal artery perforator, provides for reconstruction of the muscle tendon deficit, if the vascularised superficial peroneal nerve fascicle is also harvested, it will facilitate functional reconstruction.The skin island is useful for both post op monitoring and reconstruction of skin defect.

Treatment strategies for these malignancies have radically changed. It has been demonstrated beyond doubt that treatment by experienced surgeons will improve outcomes.[3]

Thus the flow through fibula osteocutaneous flap provides an avenue for the reconstruction of all the components of complex composite sarcoma resections. The use of neoadjuvant chemotherapy and post operative radiation adds to the locoregional disease control.

AIM OF THE STUDY

To evaluate the free fibula as a flow through flap for reconstruction of upper limb defects after sarcoma excision.

To assess the functional and aesthetic outcomes after upper limb reconstruction using free fibula flap.

Evaluation of outcomes takes into account the following:-

- Overall patient satisfaction.
- Functional outcome assessed by the MSTS scoring system.
- Cosmetic acceptability of the patient by visual analogue score.
- Complications after surgery
- Donor site morbidity.

SURGICAL ANATOMY

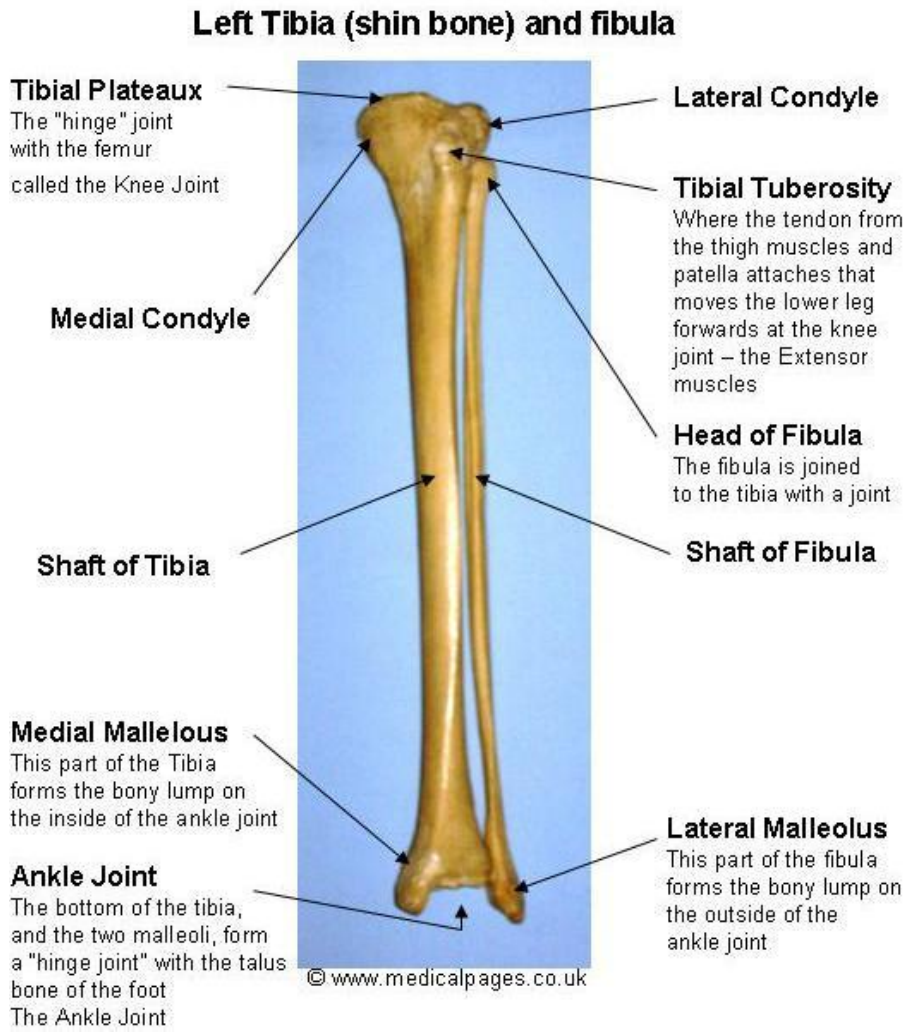
The fibula, a cortical bone, does not participate in weight bearing. It is of importance to note that almost the entire length of the fibula can be harvested leaving behind only 6 to 7 cms of bone at both ends. This is to preserve the integrity of the ankle and knee joints. It is raised based on its supply from the peroneal artery and venae comitantes, and it can provide a maximum of 30cms of free vascularised bone graft.

The fibula has 3 borders- anterior, posterior and interosseous. The anterior border is directed laterally and the interosseous border is directed medially. Posterior border is directed posteriorly and is less distinct. The anterior and posterior intermuscular septum is attached to the anterior and posterior borders, whilst the interroseous border gives rise to the interosseous membrane.

Muscle Attachments:

It has three surface- medial, lateral and posterior.The biceps femoris is the only muscle that pulls the fibula up, while the rest pull it downwards. A total of 9 muscles are attached to the fibula.

Lateral Surface: Origin of peroneus longus and brevis. Longus from the upper two-thirds and brevis from the lower third.



Medial Surface: Attachment of Extensor digitorum, Extensor hallucis longus and peroneus tertius muscles.

Posterior Surface: Soleus, Tibialis Posterior and Flexor hallucis longus.

The deepest muscle in the posterior compartment, the tibialis posterior lies between the flexor digitorum and hallucis muscles. Flexor hallucis longus takes origin from interroseous membrane and from either side from tibia and fibula.

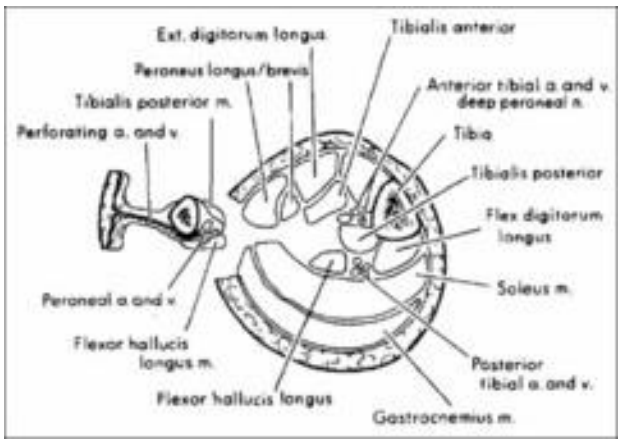


Figure showing Plane of Harvest of the Fibula Flap

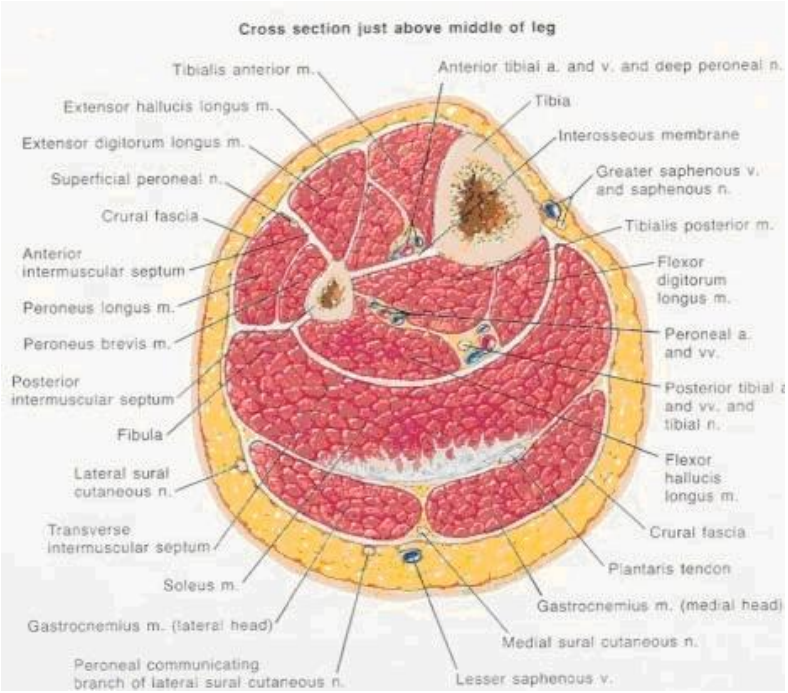
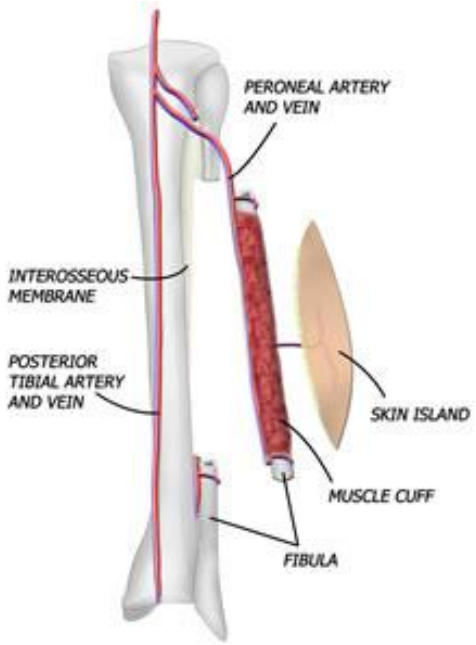


Diagram shows the intimate relation of the Fibula with the Peroneal Vessels and also its relation to the muscular attachments

BLOOD SUPPLY

The posterior tibial artery gives rise to the peroneal artery about 3-4 cms distal to the origin of the anterior tibial. It courses intimately with the fibula running parallel to it. It lies between the flexor hallucis and tibialis posterior. Sometimes it is also found within the substance of the flexor hallucis. The peroneal artery gives multiple arcuate arteries which form the periosteal supply to the fibula. Also these vessels perforate the muscles and emerge as musculocutaneous perforators to the posterolateral aspect of the leg. It is of clinical importance to note that these perforators emerge from the posterolateral septum. The nutrient artey that forms the endosteal blood supply enters the fibula at its midpoint. The mid third of the fibula is richly vascularised due to this.



Diagrammatic representation of the Fibula along with muscle cuff and skin paddle

The peroneal artery becomes the lateral calcaneal artery below the lateral malleolus. The artery has an external diameter of 2-2.5mm at its origin and about 4-6 cm pedicle length. The venous drainage of the fibula flap is primarily through the two veanae comitantes accompanying the artery. The vein themselves have an external diameter of 2-4mm.

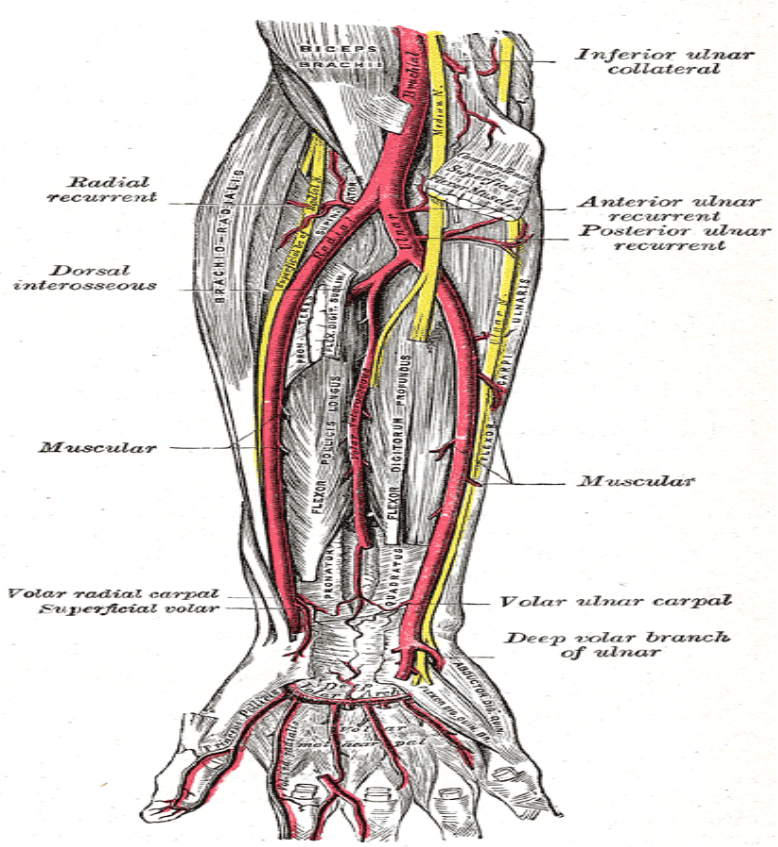
NEUROVASCUALR PATTERN IN THE FOREARM

The brachial artery divides into ulnar and radial halfway down the cubital fossa.

The *radial* artery passes distally across the supinator, pronator teres, radial half of flexor digitorum superficialis(FDS), origin of flexor pollicis and finally lower end of radius. In the lower part of the forearm it disappears beneath the abductor pollicis longus and extensor pollicis brevis tendons. In the upper part it is underneath the brachioradialis, closely associated with the superficial branch of radial nerve.

The *ulnar* artery passes deep to pronator teres and beneath FDS near the median nerve. It then leaves the median nerve and lies over the FDS with the ulnar nerve on the ulnar side. It continues as the superficial palmar arch across the wrist. It is intimately associated with the Flexor carpi ulnaris in the forearm. The most important branch of ulnar is the common interosseous artery. It divides into anterior and posterior

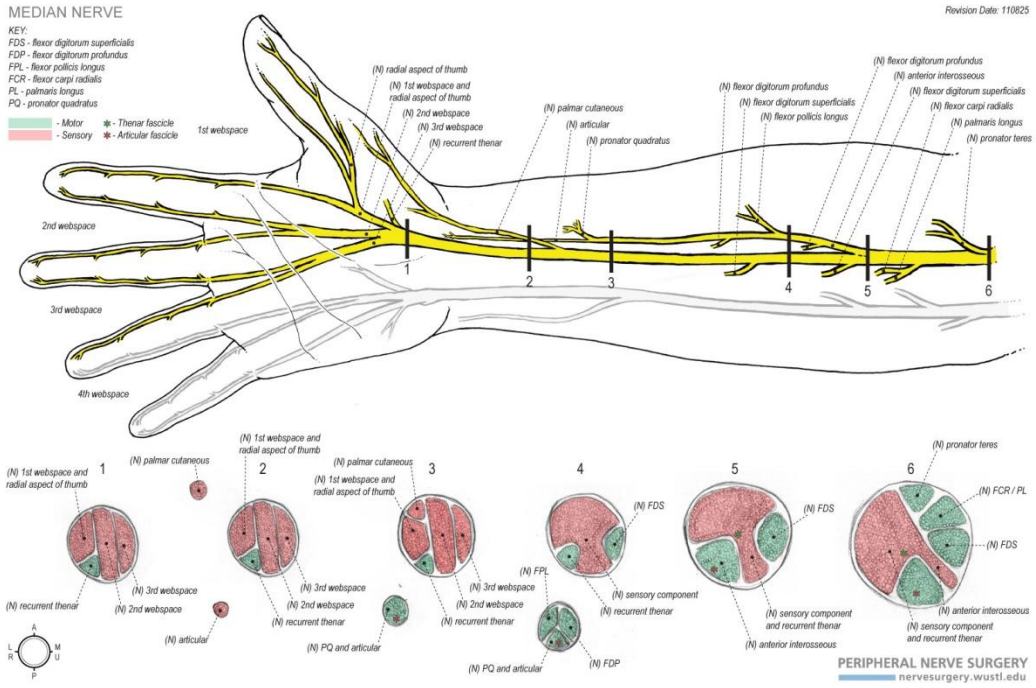
branches. The anterior interosseus supplies the FDP and FPL muscles. Posterior interosseus artery passes through the interosseous space and comes to lie dorsally.



NERVES OF FLEXOR COMPARTMENT

The *median nerve*, gives a branch to pronator teres at cubital fossa. Beyond this it supplies the flexor carpi radialis and Palmaris longus, and then joins the ulnar artery at the flexor arch. In the middle of the forearm it emerges from the lateral border of the FDS muscle after supplying it. The anterior interosseus nerve accompanies its artery and supplies the

Flexor digitorum profundus, FPL and pronatar quadrates. The palmar branch of the median nerve is given above the flexor retinaculum.



The *ulnar nerve* passes between the two heads of the flexor carpi ulnaris to enter the volar side of the forearm. The nerve lies under the flexor carpi ulnaris, accompanying the artery throughout its course. It supplies the flexor carpi ulnaris and the flexor digitorum profundus(ulnar half). The dorsal branch of the ulnar nerve is given off proximal to the wrist.

Muscles

Superficial layer:

There are 5 muscles. Pronator teres, flexor carpi radialis, flexor digitorum superficialis, Palmaris longus, flexor carpi ulnaris.

Deep Layer:

These include flexor digitorum profundus, flexor pollicis longus and pronator quadrates. Of particular interest to us is the flexor digitorum profundus. Supplied by both median and ulnar nerves, it arises from the medial surface of the olecranon, ulna- upper third and also the interosseus membrane. The index tendon separates from the other 3 fingers in the forearm. The tendons are inserted into the distal Interphalangeal joint base. The primary action of the FDP is it flexes the terminal interphalangeal joint, and also rolls the fingers and wrist. A great gripping muscle, in full power of contraction wrist extension is indispensible.

MATERIALS AND METHODS

In our department, between March 2012 and March 2014 we have done 6 cases of upper extremity Sarcoma reconstruction, all involving the forearm region. The following criteria were decided upon for patient selection

Inclusion criteria:

- Patients with soft tissue sarcoma (biopsy proven) of the upper limb.
- Patients with good IQ who understood the treatment explained to them.
- Patients who are fit for surgery.
- Patients willing for long term regular follow up.
- Patients who received previous chemo/ radiation were also included.

Exclusion Criteria:

- High risk individuals who are medically unfit.
- Patients not willing for follow up.
- Patients not willing for long duration of surgery and for the postoperative physiotherapy rigors
- Elderly patients.

Preoperative Protocol:

A thorough history was taken from all the patients regarding the nature of the illness, duration, progression of swelling. H/O previous surgeries, chemotherapy or radiation were documented. Personal history especially smoking was asked that would preclude immediate reconstruction with a microvascular flap. If the patient was a smoker our protocol is to advice complete abstinence for 3 weeks before the procedure.

Clinical examination was done in all the cases to determine nutritional status, level of willingness and intelligence. The forearm is assessed for scars of previous injury/ surgery that could have compromised a blood vessel. Presence of the palmar arch is confirmed(clinical examination inclusive of Allen's test) in all the patients. The handedness of the patient is also taken into consideration.

Donor site was assessed clinically for the presence of pulsations in all 3 major vessels(peroneal, anterior and posterior tibial). Presence of any scars, venous insufficiency were noted.

Management of the patient was then discussed with the multispeciality integrated tumour board, comprising the consultants from Surgical oncology, Plastic surgery, Medical oncology, Radiation therapy

and occupational therapy. A consensus in the management is then arrived in the planning session for the various reconstructive options.

A 8 Hz hand held Doppler is used to examine the patients at both donor and recipient sites. The location of perforators for the skin paddle from the peroneal vessels are marked preoperatively. We did not do CT angio of the leg routinely. If the anterior and posterior tibial arteries were not palpable clinically, then peroneal artey dominance was ruled out.

Preoperative work up includes routine MRI with T2 weighted images in all cases. MRI is done to assess the involvement of vital structures- vessels, nerves and muscle tendon units. We had a total of 6 patients in our study. Of these in 4 cases both the radial and ulnar artery segments were resected with the tumour. In the other 2 cases the ulnar artery was spared, the resected radial artery was confirmed to be the dominant/codominat vessel, producing on table hypoperfusion of the ulnar border of the hand. So in all the 6 cases we have reconstructed vascular, bony, muscle tendon and skin defect by the flow through osteocutaneous flap.

In all patients after explaining the pros and cons of LPS an informed consent was taken. The ability and intelligence quotient to cooperate for post op physiotherapy and neoadjuvant chemotherapy were also assessed for careful patient selection

SURGICAL TECHNIQUE

After the completion of the resection by the surgical oncologist, the tourniquet was removed and 20 minutes of perfusion allowed. The vitality of the hand and the defect were examined. In those patients were the oncologist was certain of resecting the tumour with both the vessels, simultaneous 2 team approach was followed. In those cases were one vessel is resected, simulataneous harvest was done, but the distal peroneal artery is not ligated until the need for a flow through flap was discerned. In the first scenario, were both vessels were resected, straightaway the distal end was prepared for anastomosis and flap is harvested.

Harvest of the fibula

We followed the posterolateral approach for flap harvest because it is easy to maintain the perforator to the peroneus longus in this approach. A pneumatic tourniquet was inflated to 300mm Hg. For enabling dissection, the knee if flexed to 135^0 and hip flexed to 60^0 and internally rotated.

A line is drawn from the head of the fibula to the lateral malleolus. The midpoint of this line represents the site of entry of the nutrient vessel to the fibula. The skin paddle is primarily harvested to be used as a tool

for flap marking post operatively. Skin incision is made along flap margins and extended on either direction depending on the length of fibula required. Anterior incision is done first and the anterior septum identified and incised. The attachment of the peroneus muscle to the fibula is separated carefully. Peroneus longus muscle tendon unit as required for the deficit is harvested with little extra length. The blood supply for this muscle is from the perforator from the peroneal vessel. During the harvest of peroneus longus the dissection on the lateral side of the fibula is between periosteum and muscle to increase the 3 Dimensional positioning of muscle. The rest of the surface is harvested with little cuff of soleus, peroneus tertius and FHL muscles.

Dissection is proceeded close to the fibula separating the extensor hallucis, digitorum and peroneus tertius muscles, Interroseus membrane is incised after taking care to protect the anterior tibial vessels and deep peroneal nerve. Dissection is then continued posteriorly. The posterior incision made and the posterior septum identified. The perforators are visualised coming through this septum. Dissection is proceeded separating soleus and Flexor hallucis longus fibres. Now the periosteum is incised anteriorly and subperiosteal elevation done, care taken to protect peroneal vessels. Preplating was done before osteotomy to know

the exact dimension of the bone segment, vascular segement, muscle tendon segment and skin paddle dimensions.

The remaining muscle attachments are separated and peroneal vessels are made visible. The same technique of fibula flap harvest is used except special attention is paid for harvesting proximal and distal peroneal artery with adequate length to allow tension free anastomosis at the recipient site.

Compression plates with screws was used for skeletal continuity reconstruction and K wires for wrist arthrodesis. Some cases a combination of both were used. The order of reconstruction was bone, vessels and the muscle tendon unit. The long flexor muscle mass with its intact neurovascular bundle were sutured to the proximal part of the Flexor digitorum Profundus muscle. Distally peroneus longus tendon was weaved into FDP residuum at or proximal to carpal tunnel. The defect between the proximal and distal ends were bridged with peroneus tendon using nonabsorbable prolene sutures. When the extensor muscle tendon gap was encountered the wrist was arthrodesised in 30 degrees extension, and wrist extensors was transferred to the EDC. The skin paddle is sized down to the defect during final closure.

Post op Course

Hand elevation, external POP slab (with a window for skin paddle monitoring) splinting the hand in functional position. The POP slab was continued for a period of 4 weeks, after which the patient was educated about care of the insensate hand. After this passive stretching protocol for joints of the hand is started with night splinting for another 4 weeks. Active movements are encouraged in hand joints with proximal joint exercises after 8 weeks.

Of all the 6 patients, 5 flaps had no complications. 1 flap was salvaged by correction of venous thrombosis, with a vein graft. All our patients gained light touch at an average of about 4 months along with large diameter fibre pain and temperature recognition. Functional aspect of recovery was tested by 2 independant observers. All assessments were done at the end of 9 months using the MSTS scoring system.

REVIEW OF LITERATURE

Sarcoma is a malignant neoplasm arising from transformed connective tissue cells that originated from embryonic mesoderm. The tissues include adipose, cartilage, muscle and bone. Commonest presentation in the extremity is asymptomatic, however they can produce symptoms if they involve the nerves or vessls.[4]

Aetiology

Tumor suppressor genes Rb-1 and p53 alterations are detected in a sizeable proportion of sarcomas.[6,7] Radiation has long been thought to be an important predisposing factor for sarcomas. Diseases especially breast cancer, lymphomas, and cervical cancer[8] have been studied for the effects of radiation. Some studies suggested a link between phenoxy herbicide exposure in forestry workers, farmers, and railroad workers and subsequent development of sarcoma.[9]

Soft tissue sarcomas occur in any site throughout the body. 43% are in the extremities, in this two-thirds of extremity lesions occur in the lower limb. 34% are intraabdominal, divided between visceral(19%) and retroperitoneal(15%) lesions.

The classification for the staging of sarcomas of the hand were decribed by Ennekin et al. It takes into account grade(G), site(T), and metastasis(M) which are determined by histological, radiological and clinical criterion.

Grade: G0- benign lesions, G1-low grade, G2- high grade.

T0- benign intracapsular and intracompartmental lesion.

T1- intracapsular lesion

T2- intracompartmental lesion.

M0- No metastasis, M1- metastasis present.

It has been proved that G1 lesions have a low metastasis risk (25%), are well differentiated and have fewer mitoses and a moderate cellular atypia. G2 lesions are highe grade with increased risk for metastasis.[5]

Enneking's classification system of musculoskeletal sarcomas of the hand

Stage	Grade	Site	Metastases
IA	G1	T1	M0
IB	G2	T2	M0
IIA	G1	T1	M0
IIB	G2	T2	M0
IIIA	G1–G2	T1	M1
IIIB	G1–G2	T2	M1

Investigations

1.CT or MRI: An important issue for the surgeon is to identify the relationship of the sarcoma to neurovascular structures. An MRI gives valuable information regarding the proximity of the sarcoma to the vital structures.

2. **Positron Emission Tomography:** PET is primarily used in the identification of unsuspected sites of metastasis in high-grade tumors

3. **Tru-Cut Biopsy:** Trucut provides increased accuracy, at least for malignancy and grade.[10]

Treatment:

Limb preserving surgery is currently the cornerstone of treatment in patients with upper extremity soft-tissue sarcoma. The reconstructive surgeon is a part of a multidisciplinary team and it is of paramount importance he has a thorough understanding of the whole treatment concept. This is because the reconstruction will have bearing on post operative treatment of the patient, such as radiation.

The status of local margins is the most important factor that influences local control. Profound anatomical knowledge is critical to avoid incomplete or unnecessary resections, which will jeopardize the

reconstructive options. The ideal situation is if the hand surgeon himself performs the resection followed by primary reconstruction. It is well established that positive surgical margins increases the risk of local recurrence and ultimately decrease survival.[11]

Surgical Margins:

Enneking et al described 4 types of surgical margins.[5]

1. *Intralesional resection*- through the plane of the tumour. Gross macroscopic tumour left behind.

2. *Marginal resection*- through the pseudocapsule or reactive zone. Satellite or skip lesions left behind.

3. *Wide resection*-removal of the mass with normal tissue, but resection confined to the relative tissue compartment. Skip lesions may be left behind.

4. *Radical resection*- removal of the entire intracompartment and extracompartment . Eg-radiocarpal disarticulation.

The tumor must be completely excised with a cuff of normal tissue in order to ensure clear margins. Many authors suggest a margin of 4 cm of healthy tissue in sarcoma of the upper extremity[15]. Eilber et al have published a paper saying that as less as a 1 cm margin is enough.[14]In case

of the hand even 1 cm of normal tissue may lead to severe compromise of function. Till now there is insufficient evidence to support a specific recommendation, but most studies take to the fact that a 1cm margin is acceptable provided major nerves are not involved.[12,13]

Management of peripheral nerves

In sarcoma there always needs to be a balance between radical resection and nerve salvage. Today our techniques permit us to reconstruct most tissues such as bone or vessels immediately. However, reconstructive options for the peripheral nerves are still limited. Resections for sarcomas of the extremities is generally accompanied by a considerable loss of function. It is noteworthy to take into account the fact that the invasion of nerve fibers by sarcoma is rare. In most cases the affected nerve has to be resected with the primary tumor. In the past few years, the concept of achieving clear margins if a major nerve is involved has changed.

Gerrand et al[16] in the year 2001 introduced the concept of planned positive margins. He studied a total of 566 patients in whom the tumors were involving the major nerves. He found that with proper preoperative planning , excision combined with radiation was not associated with any increase in local recurrence. Clarkson et al[17] showed that in patients

where the sciatic nerve was encased on less than 270^{o} of its circumference, there was no increase in local recurrence after epineural dissection followed by radiation . Kemp et al observed no local or distant recurrences after planned marginal excision with epineurectomy. His study included 8 patients with upper limb liposarcoma and complete forearm nerves entrapment.[18]

Reconstruction

It is ideal to proceed with the reconstruction immediately after the resection as a single staged procedure. Reconstruction may be delayed if absolutely necessary.

Siegel et al had used vacuum assisted treatment for postoperative radiation induced complications and he proved that it did not compromise outcomes.[19]

Preoperative radiation is a factor that need to be taken into account. If the patient had received radiation, the vascular anastomosis should be placed outside the radiation field, if a free flap is planned. In most cases interposition grafts are required.

Reconstruction after radiation

Tumours less than 5 cm can be treated with resection alone. Above this size all tumours are treated with radiation.[20] Davis et al, showed a

high incidence of postoperative wound complications in patients who have received preoperative radiation. Also they observed a high incidence of joint stiffness and edema in patients who received post operative radiation. From a reconstructive point of view, in patients who have received preop RT, it complicates microvascular reconstructive procedures because of compromised tissue quality. Also post op tissue edema and stiffness greatly hinders our physiotherapy which is very important for patient rehabilitation. [21]

Payne et al did a study on 113 patients who underwent upper limb preservation following sarcoma resection.They concluded saying that the upper limb activity and function was satisfactory in both free and pedicled flaps. They also found no differences in post op complications between the two groups. [22]

Reconstruction of skin, bone, and vessels

Resection of the tumour results in complex defects of bone, muscle, nerves and vessels. It also leaves a dead space. As the availability of local flaps are limited, free flaps are often necessary to obtain wound closure. Options include the anterolateral thigh flap, the lateral arm flap, and flaps from the subscapular system.The advantage of using a muscle

flap(gracilis), is that it can serve as a functional transfer to reconstruct resected motor units. In areas with thin skin coverage (the dorsum of the hand) a thin, pliable cutaneous flap- the lateral arm flap have been found to be both reliable and cosmetically superior.[23]Complete resection of bones is uncommon, because the periosteum is usually considered an adequate surgical margin. In case of segmental bone loss, nonvascularized or vascularized bone grafts (free fibular grafts) may be used to restore continuity of the bone. Ghert et al[24] observed a significant increased in complications with only minor benefits, in cases of reconstruction of vessels .

Nerve reconstruction

Segmental resection of the nerve entrapped by the tumour, yield highly unpredictable return of function after reconstruction.[25] Whenever possible it is better to avoid resection of the nerve and opt for an epineural dissection.[16]There are 3 factors that influence outcome after nerve reconstruction

a. Length of defect: Shorter defects that are bidged by nerve conduits provide better results[28]
b. Favourable results are achieved if distal nerve is involved as it contains predominantly motor fibres.

c. Patients age .

If resection of a segment of nerve is inevitable, primary tendon transfers or distal nerve transfers have to be considered.[26,27]

Amputation

Ghert et al in their study defined certain scenarios where amputation need be considered

a. When more than one major nerve is lost the morbidity is so high that amputation is considered.
b. Infiltration of interrosseous membrane.
c. Advanced disease with extensive loss of functional tissues.
d. Severe comorbidities that preclude major reconstructions.[29]

According to Ottaviani et al the quality of life is comparable between amputees and limb salvaged patients.[30]

When amputation is inevitable, the distal part can be used as a fillet flap to allow coverage of large defects.[31] There have been instances where post resection the remaining distal forearm or hand has been replanted.[32] Spare parts surgery has been proved to be oncologically sound in a large series of patients.[33]

Horowitz et al published a paper on a study of 93 patients with Sarcomas of the lower limb that were reconstructed with prosthesis.[34]

They reported an event free prosthetic survival of 88% in proximal femur after a mean follow up of 60 months. The rates however decreased to 50% in proximal tibia. Limb survival at 5 years follow up was about 80% for all the areas. Wound necrosis was the most important cause of prosthesis removal.

A similar study was done by Dr.Mahivahanan et al from Madras medical college. They studied 4 patients with sarcoma,3 in upper extremity and one lower limb. According to Enneking's classification 3 patients had Stage IIB disease. Defects were reconstructed with a proximal humerus prosthesis in 2 patients and elbow prosthesis in one patient. At 40months follow up2 patients developed recurrence and their survival rate was 50%.[35]

Fein et al studied the effect of radiation on patients with soft tissue sarcoma. As the resection margins are less to save the limb, post op radiation is of paramount importance to prevent recurrence. Patients with Grade 3,larger tumours positive margins were given higher fraction(> 62.5 Gy). They noted that the 5 year local control rate was 95% in this group in comparison to 78% in the other who received <62.5 Gy. Hence they concluded that patients with extremity soft tissue sarcomas,

improved local recurrence control was seen with higher dose of radiation.[36]

Vascularity of the peroneus Longus:

1. Peterson et al used injection techniques and IHC to study the vascular pattern of peroneal tendons. They found that the main supply is from peroneal artery and distal part is from medial tarsal artery. They identifies 2 avascular zones in the peroneus longus tendon. One is in the region where the tendon curves around the lateral malleolus. The other is distally where the tendon wraps around the cuboid.[37]

2. Cho et al have studied the pattern of blood supply to the peroneal longus. In a total of 24 flaps, 86 perforators were dissected and documented. Of these 22 were musculocutaneous, 31 were septomusculocutaneous and the remaining 33 were septocutaneous. They also noted that the septocutaneous perforators were located more distal. The total number of muscular branches to peroneus was 62. The branches were concentrated between a distance of 8 and 16 cm from the fibular head.[38]

Anatomical variations and role of CT Angio:

Rosson et al studied the vascular pattern of lower limb and found the incidence of PAM(peronea arteria magna) was 5.3% among 93 patients studied. In their study they concluded that preoperative MRI was a cost effective useful investigation that can avoid unnecessary harvest failures. In those patients where MRI was unequivocal CT angio was used.[39]

Patrick et al in their study found that CTA(CT Angio) could accurately predict type of perforator in 93% of cases, size in 66.7%. In 25% of cases skin island and osteotomy were modified based of CTA findings.2 patients had hypoplastic posterior tibial artery and so the other leg was used. Thus they concluded by saying CTA is a valuable tool for predicting the course and location of perforators of peronela artery.[40]

Yvonne et al have also advocated the use of CTA to assess the vascular pattern of the lower limb before flap harvest.[41]

Nasaya et al in their study said that MRA is the investigation of choice for location, position of the peroneal perforators.[45]

Diego et al have done a study on the perforator size and number in lower limbs with the help of CT angio. They conclude by saying that

there is a high variability in the vascular pattern of lower limb. Hence there is definite role for CTA in fibula flap harvest.[42]

Choi et al[49] did a cadaveric study in 63 legs. He demonstrated that the area between the middle and lower thirds of fibula have the most concentration of both musculocutaneous and septocutaneous perforators from peroneal artery. The ratio of musculocutaneous to musculoperiosteal perforators were 2:1.

Fuchang wei in his book described the incidence of peronea arteria magna (hypoplasia or absence of both anterior and posterior tibial arteries) to be 8%.[43] **Erifukaya et al** have also studied the vascular pattern of lower limbs[44].Both fuchang and Erifukaya are of the opinion that preoperative CTA is not an absolute necessity. The incidence of PAM is considerably very low and absent anterior & posterior pulsations can be easily picked up by clinical examination and hand held Doppler.Only in patients were the pulsations were doubtful CTA was done.

Wang et al in 2011 studied the value of CT angiography and three dimensional lower limb reconstruction using vascularised fibula flap. They concluded that the course and thickness of the peroneal artery was relatively invariable.

Mamoon et al in 2007, have done a similar study using free fibula flap for reconstruction of upper limb sarcomas. In total they had treated

23 patients of which 18 patients had a tumour in humerus and 5 in radius. In their series osteogenic sarcoma was the commonest tumour. In their series for 11 patients a second flap in the form of a pedicled latissimus dorsi flap was used to cover the soft tissue defect. 8 patients required secondary procedures such as tendon transfers, flap readjustment. They found a good overall patient satisfaction in 21 out of the23 patients who had a post op useful limb.[46]

The cornerstone of limb preservation surgery is the functional result of the limb. The MSTS- Musculoskeletal Tumour Society grading system is used to assess the functional restoration. This has been described for each joint such as shoulder, elbow, wrist. Six parameters are evaluated and each is given a score of 0 -5; 0 being a worst score and 5 the best possible. Then the 6 are totalled and a score of 15 and above is considered acceptable.

MSTS functional evaluation system for upper limb salvage following tumour resection

	Pain	Function	Emotional acceptance	Position of hand	Manual dexterity	Lifting ability
5	None	No restriction	Enthused	Unlimited	Normal	Normal
4	Intermediate					
3	Modest	Recreational restriction	Satisfied	Not above shoulder or no pro/sup	Loss of fine movements	Limited
2	Intermediate					
1	Moderate	Partial disability	Accepts	Not above waist	Cannot pinch	Helping only
0	Severe	Total	Dislikes	Flail	Cannot grasp	Cannot

BONE UNION

1. Mamoon et al had 1 patient who had a fracture of the graft and it was treated by casting. When patient resumed function and load bearing was possible with no discomfort, bone union was presumed to have taken place. It took an average of 7 months for this to occur.[46]
2. Reconstruction using vascularised fibula graft alone takes about three months to unite.[47]
3. Hsu et al observed that 90 % of the patients achieved union at average of 7.6 months.[48]

COMPLICATIONS:

1. In the study conducted by Mamoon et al,[46] they encounterd one patient with Malignant fibrous Histiocytoma of the upper humerus. She had a history of recurrence. 8 months postoperatively patient developed another recurrence with distal edema that necessitated a shoulder disarticulation. They did not see any donor site complications except seroma associated with latissimus donor site. Their overall complication rate was about 29% after a 5 year follow up.

2. Andre et al[52] did a series of 25 consecutive mandibular reconstructions with free fibula flap over a 4 year period. They reported a relatively high complication rate of 56%. 10 patients required revisional procedures. And 2 flaps were completely lost.
3. Arai et al[50] also reported a complication rate of 56% in their series of 60 patients. Their cases included a mix ofbenign and malignant conditions of both the limbs.

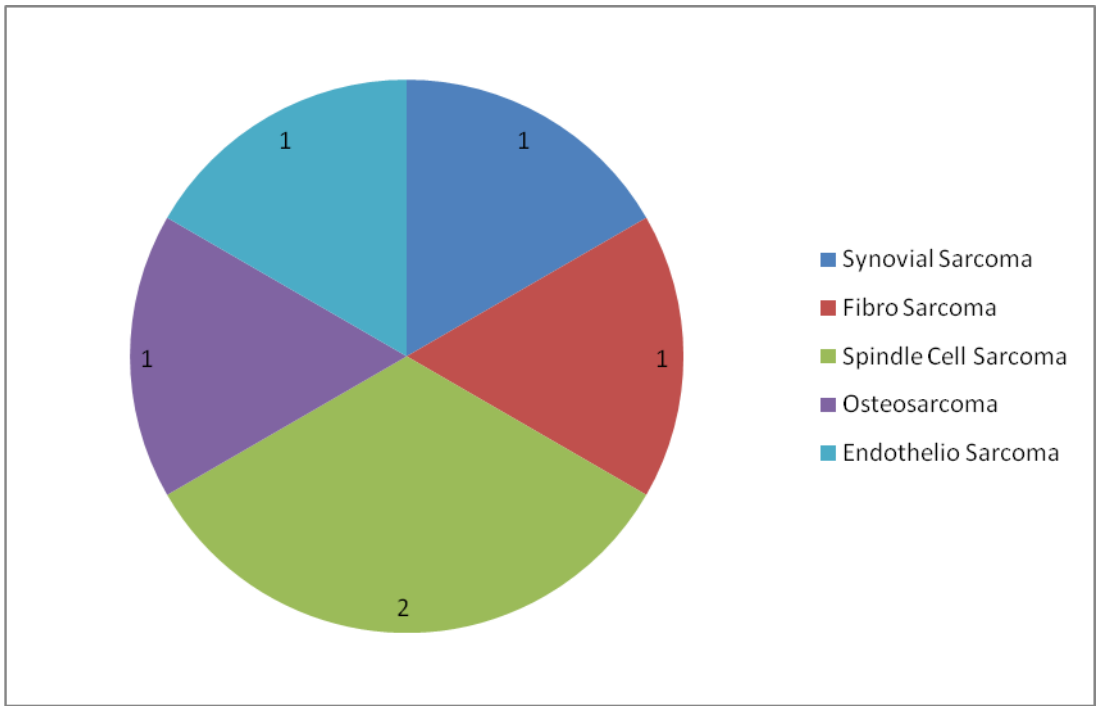
   Wood used vascularised fibula to reconstruct 29 cases of upper extremity tumours. Of this 4 patients(13.7%) developed complications. 3 patients had sepsis and one had non-union.
4. Eric et al[51] in 2004 said that complications can occur both at recipient and donor site. Thrombosis of the microvascular repair site was the most important cause for recipient site complications. Infection and sequalae of harvest contributed to the donor site complications. They also said it was important to document collateral circulation before flap harvest. This is because, in their experience, the risk of producing distal ischemia was significant after harvest of radial forearm and fibula flap .
5. Harvest of the fibula is not without its consequences. Long-term deficits after free fibula harvest have been demonstrated .Problems may range from pain, ankle instability to weakness after harvest of

the fibula. Persistent pain may be seen in upto 11% of patients undergoing harvest of the free fibula .[52] The incidence of motor weakness decreases over time .Some patients may complain of subjective weakness in the follow-up period. When the harvested legs were compared to the nonoperated leg, strength measurements at the knee and ankle are significantly decreased with isokinetic testing.[53] These complications rarely cause a disability in the patient's postoperative functioning . This should not prohibit the reconstructive surgeon from harvesting the vascularized fibular graft for reconstruction.

OBSERVATIONS AND RESULTS

A total of six patients underwent upper limb reconstruction with flow through free fibula osteomyocutaneou flap. There were a 4 male and 2 female patients. The patients aged between 19 and 40 with a mean of 30 years.

Histopathology:



Among the 6 patients 2 had spindle cell sarcoma the remaining each 1 patient had Fibro Sarcoma, Synovial Sarcoma, Osteosracoma, Endothelial Sarcoma.

STRUCTURES EXCISED

In four patients variable extent of both the radial and ulnar arteries were excised along with the tumour mass. Amongst these four patients, in three patients both the bones (radius and ulna) were removed. In one patient only the radius was removed.

In two patients a variable extent of only the radial artery was excised. One of these patients had both bones excised, and the other had only radius excised. In one patient the radial artery was found to be the dominant vessel. On resection of the radial artery, the hand developed signs of on table ischemia.

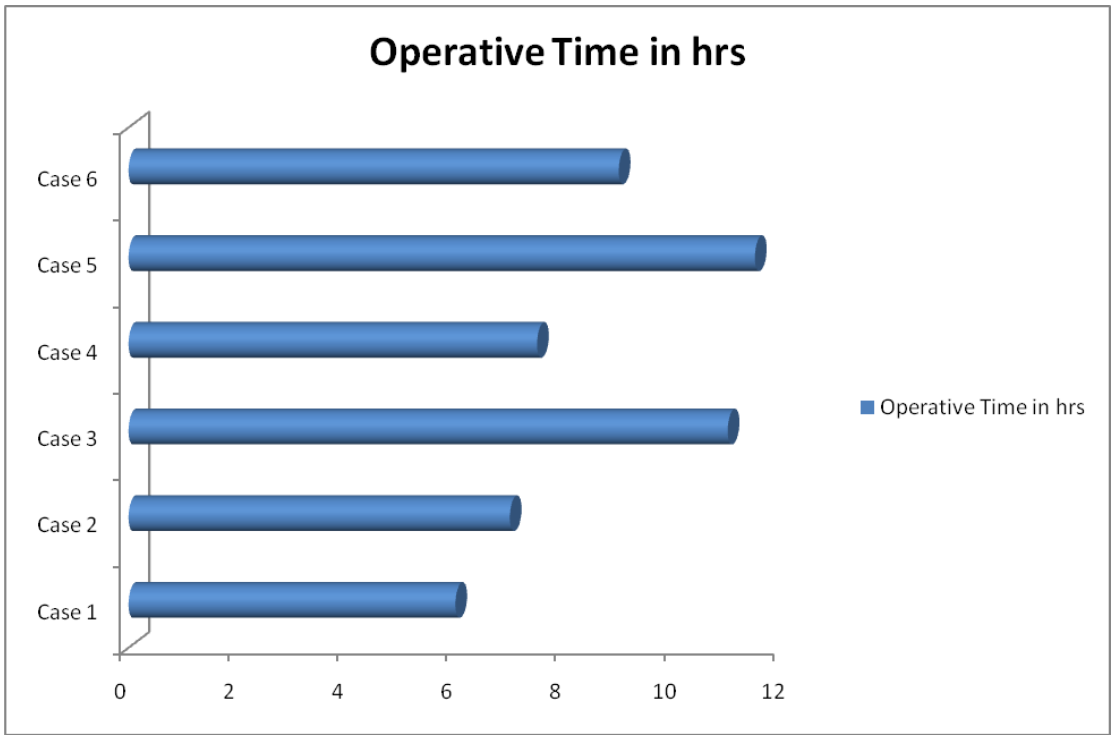
Structure Excised	Radial Artery	Radial and Ulnar Arteries
Radius Bone	1	1
Ulna and Radius Bone	1	3

OPERATIVE TIME

The operative time for the whole procedure lasted between six and eleven hours.

The shortest operating time was observed in a case of fibrosarcoma. This patient had only a segment of radial artery resected along with the radius bone.

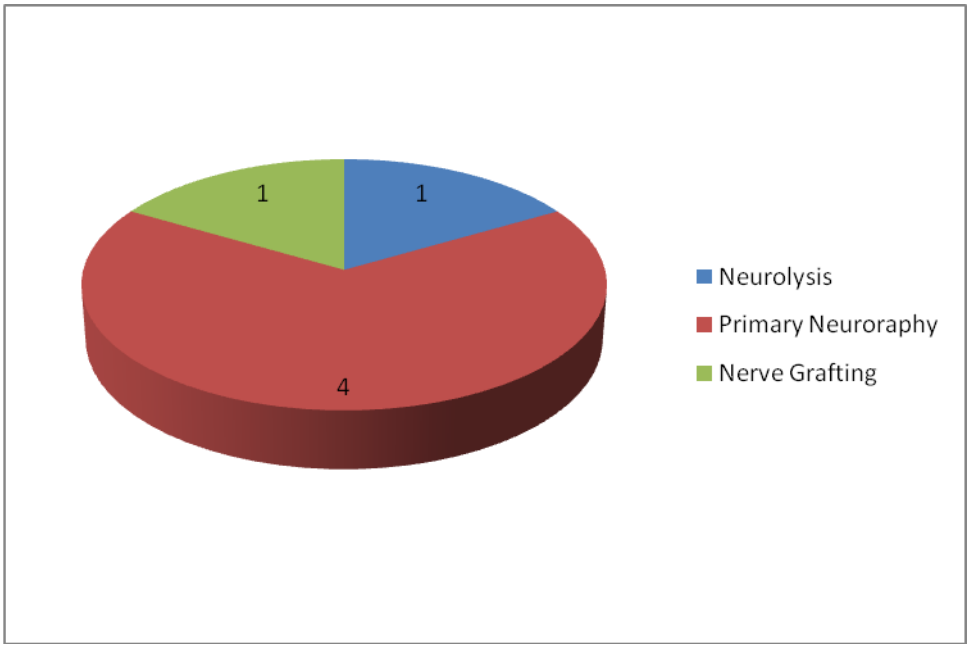
The longest operating time was noticed in a case of spindle cell sarcoma. In this patient both the vessels were resected along with both the bones. Median nerve resected as a part of the excision and it was reconstructed with the help of a nerve graft.



NERVE RECONSTRUCTION

Serial No.	Patient details	Nerve Involved	Technique of Reconstruction	Skeletal Defect
1.	20/M	MEDIAN	PRIMARY NEURORAPPHY	14 cm
2.	36/F	ULNAR MEDIAN	NEUROLYSIS	8 cm
3.	40/M	ULNAR MEDIAN	NEUROLYSIS	10.5cm
4.	22/M	ULNAR MEDIAN	NEUROLYSIS	9.5cm
5.	19/M	MEDIAN	NERVE GRAFTING	11 cm
6.	26/M	ULNAR	NEUROLYSIS	8.5 cm

The patient who required a nerve graft had a nerve defect of 3.5cm. Reversed sural nerve graft (2 cables) were used. The size of the bone defect varied from 8 to as much as 14 cm. The average size of the skeletal defect in this study was 9.5cm.



Assessment:

The functional assessment was done with the MSTS scoring system. Six parameters were included as shown in the table below.

Serial	Patient Details	Tumour	Functional Score						
			Pain	Function	Hand Position	Dexterity	Acceptance	Lifting	Total
1	20/M	SS	5	4	5	4	4	4	26
2	36/M	FS	4	3	4	4	4	3	22
3	40/M	SCS	4	3	3	3	2	3	18
4	22/M	SCS	5	4	5	4	3	4	24
5	19/M	OS	4	3	3	4	2	2	16
6	26/M	ES	4	3	4	3	2	4	20

SS – Synovial Sarcoma
FS – Fibro Sarcoma
SCS – Spindle Cell Sarcoma
OS – Osteo Sarcoma
ES – Endothelial Sarcoma

Complications

1 person developed wound dehiscence in the donor site, which healed secondarily. In 1 patient the flap was found to be congested 4 hours into the post-operative period. Patient was immediately taken to the OT and explored. Patient had arterial thrombosis and flap was salvaged with a interposition vein graft.

Total complication rate – 33%

The patient satisfaction was also assessed by means of visual analogue score – 4 point grading scale.

Functional outcome at recipient

The chart shown below displays the functional outcome in terms of patients satisfaction at the recipient site. Three variables are taken into account and given the score of 0-4.

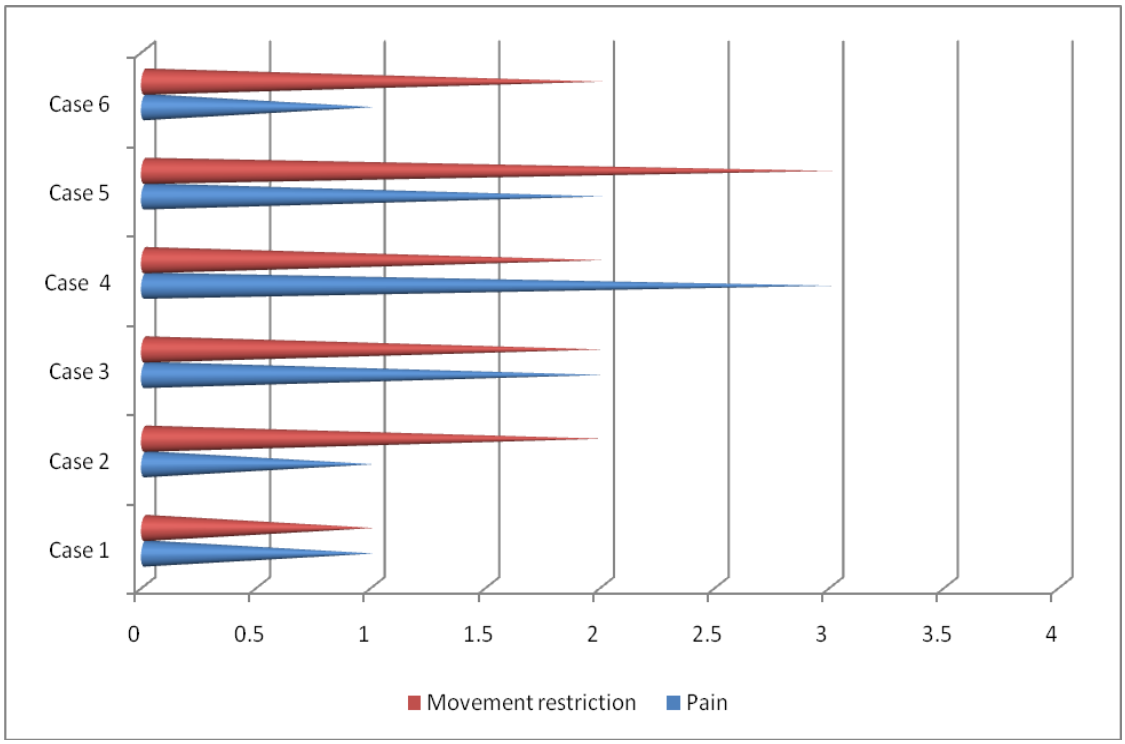
1 – never experienced

2 – rarely seen

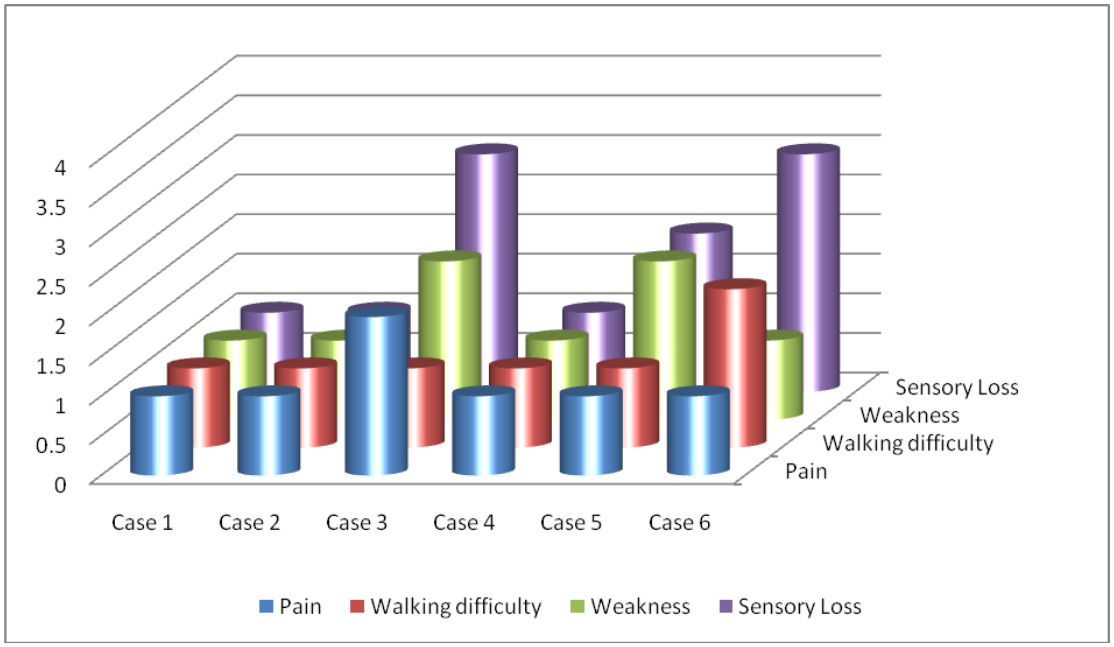
3 – often seen

4 – always seen

Functional outcome at recipient site



The functional difficulty experienced by patients at the donor site are also expressed in terms of a 4 point grading system incorporating the variables as shown in the chart below:

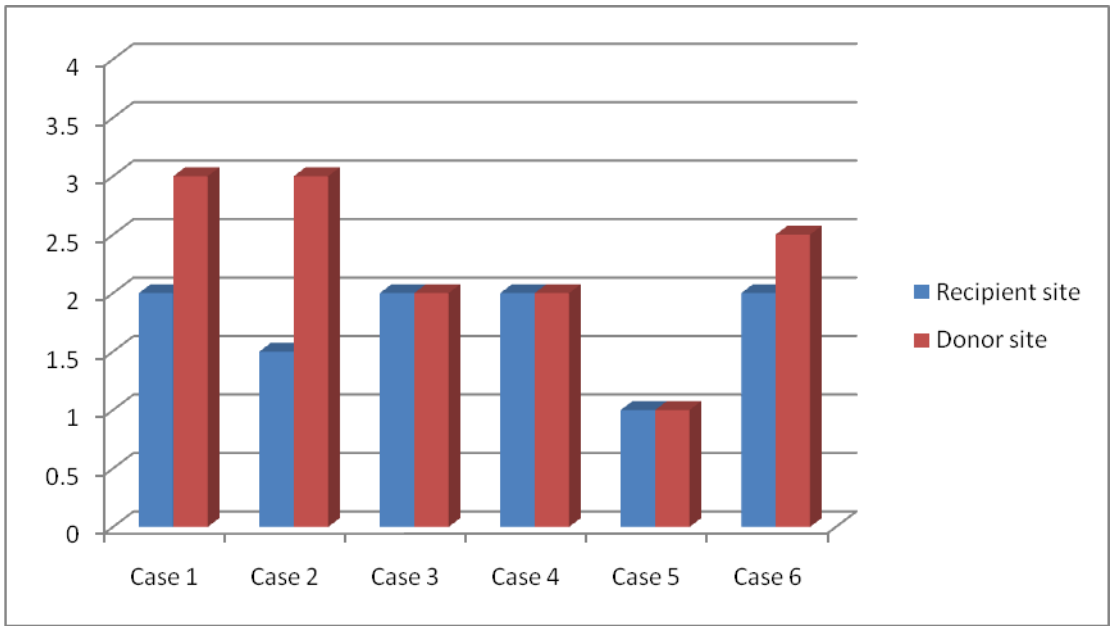


Functional outcome at donor site

In our study none of the patients had major complaints of pain or difficulty in walking after the procedure. However, 2 patients developed mild eversion weakness during follow up.

Mild paraesthesia was reported by 2 patients along the dorsom of the foot in the early post operative period, which however recovered completely on follow up.

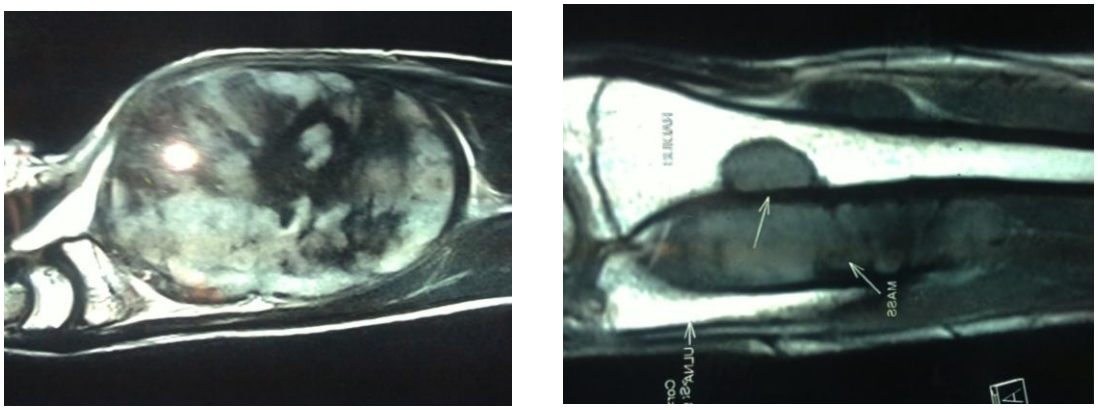
Aesthetic outcome at donor and recipient site



The aesthetic outcome according to patient satisfaction was assessed with VAS given to the patient in the followup period. The outcomes were graded as very good, good, fair or poor by the patients at both the donor and recipient site. In our study all the patients showed good to fair outcome.

CASE REPORT

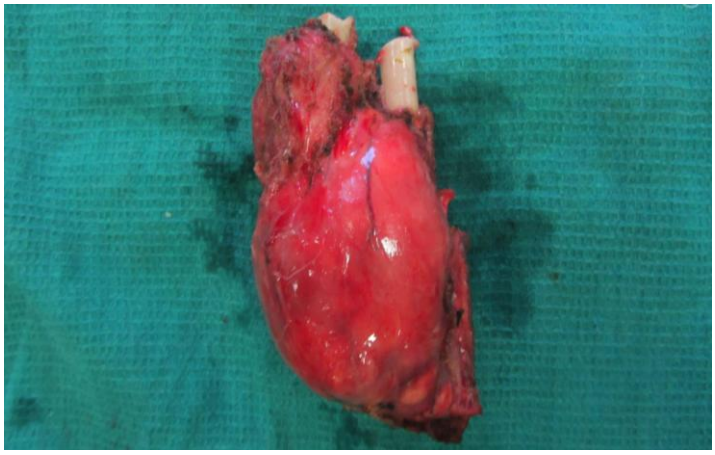
Case 1: 20 years old male with Sarcoma of the distal part of the left upper limb (Both arteries and both bone resected)



MRI Picture showing the soft tissue sarcoma in the lateral view. The tumour seen invading the radius

Intra operative picture showing resection of both bones with variable amount of muscle, tendon and nerve

Resected specimen



Flap Marking

Flap harvested with peroneous longus and skin paddle

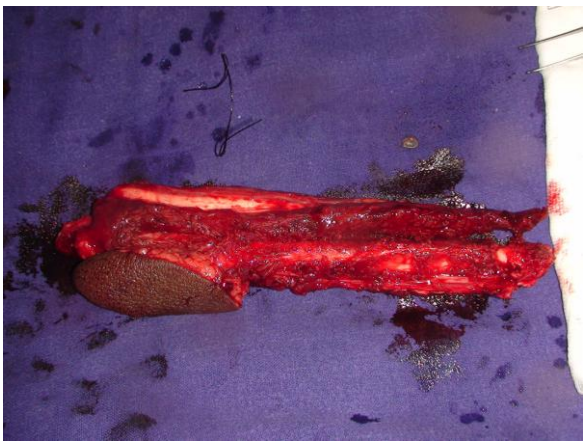


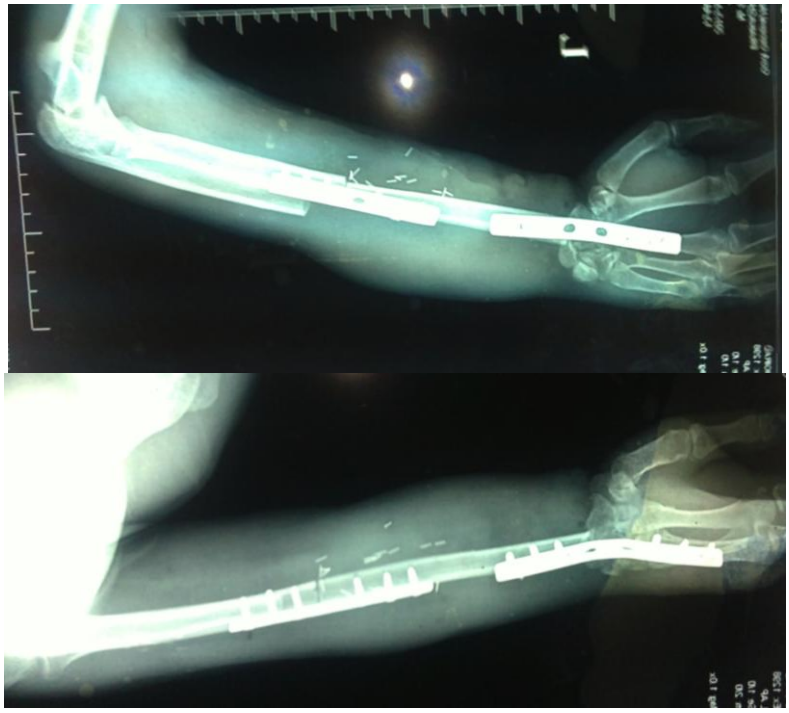
Figure 1

Figure 2

Figure 3

Immediate Post-operative

Flap fix to the remaining bone at the recipient site with plate and screws (Fig.1). Proximal anastomosis (Fig.2) and distal anastomosis (Fig.3) completing the flap in a flow through pattern.

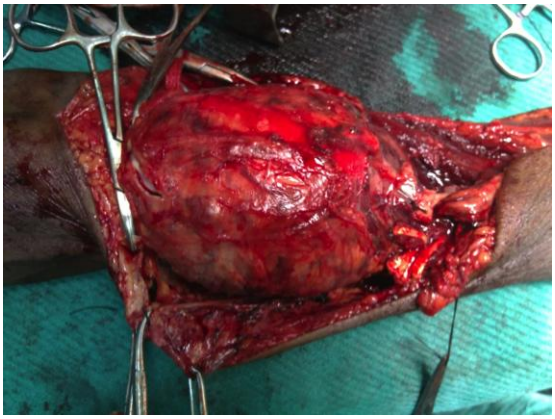


Post Op X-Ray showing wrist arthrodesis and reestablishment of bony continuity

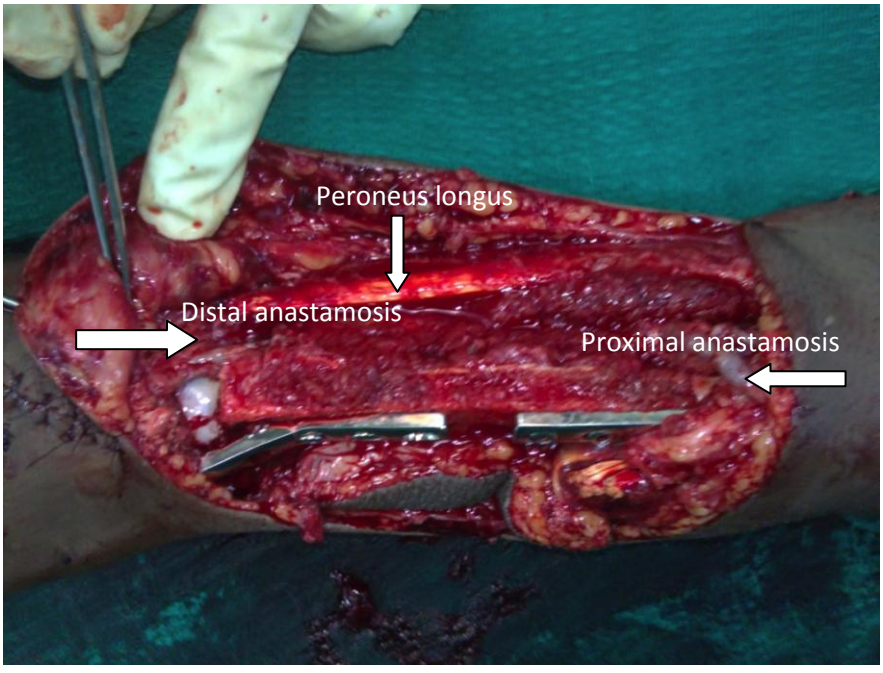
3 months Post Op showing good finger flexion

Case 2: 26 years old male with Sarcoma of the distal part of the left upper limb (Radial artery and radius bone resected)

Pre operative X-Ray showed Osteolytic lesion involving the distal end of the radius



Intra operative excision



Post op X-Ray showing the Free Fibula bridging the gap in the radius

DISCUSSION

In our department we have established, both from the oncological aspect and as well as function/form recovery, LPS is not inferior to amputation.

LPS is a boon for sarcoma forearm patients, wherein both function and form are established. Flow through free fibula osteocutaneous flap when harvested in chimeric form i.e. the skin and muscle paddle harvested on independant perforators, but supplied by the same source vessel; provides all avenues for reconstructing the composite defect.Reconstructing vessel, skeletal, Nerve gaps and the soft tissue defect in one go using flow through fibula osteocutaneous chimeric flap is a technically demanding and raison d'etre to achieve the form and function of the hand. Especially when the supportive medical oncology and radiation therapy is readily available limb preservation and salvage can be made a reality. The plastic surgeons with this new armamentarium complete the last chip of the limb preservation effort.

We found the mean age of the patients in our study to be 30 years. This was comparable to the study conducted by Mamoon et al[46] who also conducted their study in asian population. However the mean age in our

study did not match the internationally reported data which is lesser than 30 years.[54] We attribute this variation to inadequate sample size.

Conner at al[55] reported chondrosarcoma as the commonest tumour in their s tudy. Other studies have shown osteosarcoma as the commonest tumour amongst upper limb sarcomas.[46] In our study we found that the histopathology was varied. The commonest being Spindle cell sarcoma(33%).

We donot do regular preoperative CT angio of the lower limb to assess the vascular pattern of the peroneal vessel. Although there are studies to indicate the use of CTA preoperatively,[41,42] there is also enough evidence to do CTA only in select situations.[43,44] The protocol we followed was clinical examination of the leg for pulsations. This is followed by hand held Doppler(8 Hz) to locate and mark the perforators to the skin paddle. Only in those cases where there is a doubt regarding the presence/status of both the tibial vessels (to rule out PAM- peronea arteria Magana), we procure a CTA.

In the first group of 4 patients, where both the forearm axial vessels were sacrificed , the simple extra anastomosis between distal peroneal artery to radial artery in the distal forearm, which takes an extra

30 minutes establishes the vascular conduit continuity and serves to preserve the limb.In the second group of 2 patients, following the exirpation of sarcoma, the presence of ulnar border ischemia in the hand, envisage the need for the flow through free fibula osteocutaneous flap.

Peroneus Longus is harvested as a component of chimeric free fibula osteocutaneous flap. The peroneus is a type II muscle. The major pedicle from the peroneal artery was between 18 to 24 cm from fibula head in the study conducted by Cho et al.[38] In our series we found that the muscle perforator (major pedicle to peroneus) was within 2.5cm from the single best perforator from the skin paddle in all the six cases.

Reconstruction of the nerves is a crucial part of limb preservation surgery. The concept of excision of the nerve with the tumour has radically changed after Gerrand et al[16] brought in the concept of positive surgical margins. Epineural dissection of the nerve to salvage showed no increase in recurrence rates.[17] Our policy is to assess the tumour intraoperatively. If the tumour is obviously invading into the nerve, the affected segment is resected and reconstructed with nerve grafts.In the other cases, nerve is salvaged with neurolysis.

Minami et al[56] recommend partial arthrodesis instead of arthroplasty for distal radius reconstruction. Mamoon et al have studied the pattern of bone union and their suggestion is to use a single plate from

proximal to distal fragment across the fibula , instead of 2 plates. Our patients had a sizeable amount of muscle resection and hence we decided on wrist arthrodesis to give best possible function to the patient. The arthrodesis was done with wrist at 30^0 extension, with the help of K wires or plate and screws or both. The advantage with arthrodesis is patient can rehabilitate faster. There is no need for additional procedures.

We used operating microscope with 10X magnification, and we found this to be very effective with 100% patency rates of microvasular suturing. Although setting up and focus of microscope prior to suturing takes time, it has far greater advantages than operating loupes. Some surgeons use ocular loupes with 6X loupes for suturing. This can however be used only with large calibre vessel(1.5-2.5mm). Intraoperatively we employed continuous irrigation of the vessel ends during anastomosis with heparinised saline to prevent thrombus formation. Postoperatively anticoagulants such as Low molecular weight dextran and aspirin were used.

Skillful assessment of the post extirpation defect in terms of skeletal defect, muscle tendon defect, skin defect and nerve gaps paves the way for fabrication of the flap. Simultaneous 2 team approach decreases the operating time. With excellent post operative monitoring and physiotherapy regimen. All cases had good direct osteosynthesis in

the proximal and distal ends with regain of protective sensation in hand, in addition to finger flexion/extension. The skin paddle required was very less. The average skeletal defect was 9.5cm. On follow up there was no evidence of claudiction,ischemic changes. However, one patient developed pulmonary metastasis. At 9 months follow up there were no signs of any locoregional recurrence and all the flaps had settled well.

The functional assessment of all these patients were done with MSTS scoring system. 4 patients had scores of 20 and above which is considered as a good result. None of them had a score of less than 15. This is similar to the other studies where 60% of the patients had scores of 20 and above.[46]

The advantages of using the free fibula over other options are

1. Lengthy vascular pedicle.
2. Large calibre peroneal vessels for anastomosis.
3. Composite flap structure.
4. Anastomosis in a flow through pattern can serve to save the limb.
5. Acceptable donor site morbidity.
6. Simultaneous 2 team approach.

No surgery is devoid of complications. In our series we had one patient with flap congestion in the immediate post op period. This was

explored and a arterial thrombosis was salvaged with the help of a vein graft. Thus flap survival was 100%. However, one patient had wound dehiscence in the donor site which healed secondarily. Thus in total our complication was 33%.

In comparison, Andre et al[52] did a series of 25 consecutive mandibular reconstructions with free fibula flap over a 4 year period. They reported a relatively high complication rate of 56%.In their study however, they included any event with a suboptimal result as a complication.

Arai et al[50] used the simple fibular osteocutaneousflap for limb preservation. He reported a complication rate of 56%. In comparison our complication rate of 33% was trivial and manageable.However his study was elaborate with a total of 60 cases. Gao et al have reported vascularised bone reconstruction as a part of Limb preservation. None of their cases received post op radiotherapy and their complication rates were on par with us.

The free fibula provides a well vascularised composite flap to reconstruct post excisional defects of the upper limb. The anastomosis in both proximal and distal ends, enables to re-establish the vascular conduit, and in the process saves the limb. In our small study , the free fibula flap seems to be an ideal option for reconstruction of upper limb defects.

CONCLUSION

Upper limb reconstruction after sarcoma excision is a complex challenging task to the reconstructive surgeon. This is because the defect is composite, preoperative radiation makes anastomosis difficult and patient must regain acceptable function post surgery.

Sarcoma reconstruction has undergone a radical change towards preservation of the limb with the usage of the vascularised free fibula flap. The major advantage is that there is no compromise in the extent of resection. Our study and review of the literature has shown that vascularised fibula flap harvested in a chimeric pattern along with the peroneus longus provides excellent quality of tissue to reconstruct both bone and soft tissue loss. We recommend the use of the peroneus longus muscle tendon unit based on an independant perforator from the peroneal artery. The use of the peroneus muscle has improved the functional outcome in these patients.

Although the number of cases in our study was limited, results were satisfactory.

Low donor site morbidity, acceptable functional outcome, limb preservation makes the free fibula osteocutaneous flap as an ideal option for upper limb reconstruction.

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PROFORMA

FLOW THROUGH FREE FIBULA FLAP FOR UPPER LIMB RECONSTRUCTION IN SARCOMA PATIENTS

Patient's Name : ……
Age / Sex : ……
IP No. : ……
Contact Address : ……
……
……
Contact Number : ……

Preoperative details :

1. Nature of the defect ; 2. Etiology ; 3. Location of the defect ; 4. Both bones involved (Yes / No) ; 5. Both vessels involved (Yes / No) ; 6. Nerve involvement (Yes/No) [based on MRI findings); 7. Other procedures done ; 8. Pre-operative Doppler 9. Any previous surgeries in the lower limb.

Co-Morbidity : ……
Risk factors : ……
Donor site assessment : ……

Intraoperative details :

Procedure done : ……

Harvest approach (lateral / anterior) ; skin paddle size : …… ; perforator nos ….. ; length of fibula harvested ……. ; size of peroneal vessels (artery : ….. / vein : ….) length of pedicle …… ; duration of harvest …… ; tourniquet time : …… ; ischemia time ….. ; suture material ……. ; microvascular technique …….

Duration of procedure

Anticoagulants used : ……

Investigators Name / Signature : ……

MASTER CHART

Case	Age/ Sex	Ip No	HPE	Risk factors	Defect size	Skeletal Defect Size	Artery resected both ulnar and radial or radial	Bone Resected	Preop Doppler	Adjuvant Therapy	Mean operating time	Flap outcome	Complications	Functional Outcome	Aesthetic Outcome
1	20/M	8651	SS	-	7 x 8 cm	14 cm	R & U	Radius & Ulnar	Yes	Radiation	6	Settled	-	Good	Good
2	36/F	1654	FS	-	10 x 8 cm	8 cm	R & U	Radius	Yes	Radiation	7	Settled	Artery thrombosis	Pulmonary metastasis	Good
3	40/M	16212	SCS	Smoking	7.2x6.5 cm	10.5cm	R & U	Radius & Ulnar	Yes	Radiation	8	Settled	-	Good	Fair
4	22/M	36432	SCS	-	9x7.5 cm	9.5cm	R	Radius & Ulnar	Yes	Radiation	11	Wound dehiscence	-	Good	Fair
5	19/M	63837	OS	-	11 x 6 cm	11 cm	R & U	Radius & Ulnar	Yes	Chemo	11.5	Settled	-	Fair	Good
6	26/M	86001	ES	-	8 x 9.5 cm	8.5 cm	R	Radius	Yes	Chemo	9	Settled	-	Good	Good

SS – Synovial Sarcoma

FS – Fibro Sarcoma

SCS – Spindle Cell Sarcoma

OS – Osteo Sarcoma

ES – Endothelial Sarcoma

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INTRODUCTION

SOFT TISSUE SARCOMAS (STS) are rare malignant tumors arising from extraskeletal mesenchymal tissues. They are less than 1% of all newly diagnosed malignant tumors in the United States. Of these only 25% occur at the upper extremity.[1]

STS of the extremities used to be treated with amputation in as much as half of the patients. Nowadays limb-sparing surgery ,without any compromise in local control or survival rates, is performed.[2] Advances in tumour biology understanding, improved chemotherapy and radiotherapy(neoadjuvant or adjuvant in post op treatment), ability of surgical oncologists to excise the tumour with a good margin(principle of excision without seeing the tumour) and advances in plastic surgical expertise where there is a technique available to reconstruct any composite defect of the axial vessels of the hand compromising its vitality.upper extremity have all paved the way for limb salvage surgery. Oncological resections, especially in the forearm sarcomas have resulted in complex composite defects with loss of

These defects pose challenging options for any reconstructive surgeon. To envisage vitality and function of the hand, as a part of Limb Preservation Surgery(LPS), it requires a vessel conduit to bridge the

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