A COMPREHENSIVE REVIEW ON THE USE OF VASCULARIZED FIBULAR GRAFT FOR THE RECONSTRUCTION OF LONG BONE DEFECT: THE USM EXPERIENCE

by

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Preliminaries

Acknowledgment

Bismillahirrahmanirrahim...

I thank to God for His mercy and help, eventually I managed to finish this dissertation. Eventhough at the initial stage ,there were a lot of problems and obstacles in the way, with His mercy, everything was successfully settled without much difficulties.

This dissertation is specially dedicated to Dr Zulmi Wan and Dr Ahmad Sukari Halim, the consultants that are directly involved in the surgical procedures.I regard them as the father and the catalyst for the development of this surgical technique in Hospital Universiti Sains Malaysia specifically and in Malaysia in general. Without them, there won't be such a surgery in this hospital. I think nobody will be expecting that such a long and complicated surgery could be performed here and was performed by our local surgeons. Patients with bone cancers particularly, would not be able to benefit from this surgical treatment for cancer control without losing their limbs , which previous patients ended up with.

Not to forget many other personnels who were indirectly involved in the series of the surgical procedures that had been performed. May Allah bless them for their hard work and dedication.

I would like to take this opportunity to thank Dr Mohd Iskandar Mohd Amin for his great help and supervision. He had spend a lot of his time to read and correct this dissertation. Without his help and supervision, I don't think this dissertation will be as it is now. Not to forget A.P Devnani who made the writing of this dissertation happened.

To my wife ,Shiniey and children, Nadia, Adeen and my coming baby, thanks for the time and patience. I don't know how to express my deep love and care to all of you.

Thank you again.

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Abstraks

Pengenalan

Defek pada tulang selepas kemalangan atau pembuangan ketumbuhan tulang boleh dirawat dengan jayanya melalui kaedah pemindahan tulang konvensional atau secara 'bone transport'.Walau bagaimanapun bagi defek yang besar pada tulang selepas pembuangan ketumbuhan tulang setempat ,osteomyelitis kronik atau pun selepas kemalangan, pembinaan semula defek yang sedemikian adalah amat mencabar.

Pemindahan tulang fibula bervaskular menjadi salah satu rawatan pilihan sejak 1975 apabila buat pertama kalinya Taylor melaporkan kejayaan penggunaan kaedah itu untuk perawatan defek pada tulang tibia. Di Malaysia, kaedah rawatan ini masih baru lagi. Setakat ini, pembedahan menggunakan kaedah ini masih kurang dijalankan atau dilaporkan oleh mana-mana pusat perubatan. Di Hospital USM, sebanyak 19 pembedahan menggunakan kaedah ini telah pun dilakukan melibatkan pelbagai penyakit dan sebanyak 13 kes melibatkan pembinaan semula tulang pada anggota tangan atau kaki dalam tempoh 29 bulan.

Objektif

Objektif kajian ini dijalankan ialah untuk menilai kesan-kesan yang timbul daripada prosedur ini, dan seterusnya menganalisa pengalaman yang diperolehi berdasarkan penggunaan graf fibula bervaskular untuk pembinaan semula defek tulang samada dengan gabungan alograf atau tanpa alograf. Keputusan kajian ini nanti akan dibandingkan dengan kajian-kajian yang sama yang telah dijalankan di tempat lain. Ini termasuklah mengenalpasti komplikasi - komplikasi awal daripada pembedahan pemindahan tulang fibula bervaskular, mengkaji jangkamasa yang diambil untuk tulang fibula bervaskular ini untuk bergabung dengan tulang penerima dan juga jangkamasa pesakit untuk memulakan aktiviti- aktiviti harian yang biasa dilakukan dengan menggunakan anggota -anggota yang terlibat. Apabila kajian ini selesai, kami melaporkan siri pemerhatian kami daripada kumpulan pesakit yang telah menjalani prosedur yang unik ini. Pemerhatian ini kami tumpukan kepada hasil - hasil yang diperolehi daripada pembinaan semula defek pada tulang panjang menggunakan teknik pemindahan tulang fibula bervaskular.

Metodologi

Kajian ini adalah kajian analisis deskriptif ke atas tiga belas orang pesakit dari data sekunder. Terdapat dua kumpulan pesakit dalam kajian ini. Kumpulan pesakit yang pertama mengandungi 9 orang pesakit yang menjalani pembedahan pembinaan tulang menggunakan kaedah gabungan pemindahan tulang fibula bervaskular dan alograf . Kumpulan yang ke dua pula mengandungi 4 orang pesakit yang menjalani pembedahan dengan menggunakan kaedah pemindahan tulang fibula bervaskular sahaja. Jumlah pesakit yang termasuk dalam kajian ini adalah seramai 13 orang di mana mereka telah menjalani pembedahan pembinaan semula tulang anggota selepas pembuangan bahagian tulang yang berpenyakit.Semua pesakit-pesakit ini telah mendapat rawatan susulan sekurang-kurangnya untuk selama 6 bulan untuk melihat komplikasi-komplikasi awal. Penilaian dari segi fungsi dan radiografi juga dibuat dari ,masa ke semasa.

Keputusan

Seramai 13 orang pesakit telah menjalani pembedahan dengan kaedah ini, untuk memperbaiki defek pada tulang panjang berpunca dari pelbagai penyebab iaitu ketumbuhan tulang (9 kes), 'infected non-union' yang gagal dirawat dengan cara yang biasa (3 kes) dan pseudoarthrosis kongenital (1 kes). Pesakit-pesakit berumur antara 2 tahun hingga 65 tahun. Bahagian anggota yang menerima pemindahan tulang melibatkan 4 tulang femur,7 tulang tibia, 1 tulang humerus dan 1 tulang radius dan ulna. Jumlah purata masa yang diambil untuk melakukan prosedur mengeluar dan membina semula tulang ini adalah 17.6 jam. Semua pesakit telah pun menjalani pembedahan sekurang-kurangnya sekali sebelum pembedahan ini dan paling banyak adalah 7 pembedahan sebelumnya, kecuali seorang kanak-kanak berpenyakit pseudoarthrosis yang menerima rawatan ini sebagai kaedah rawatan yang pertama kali. Purata defek pada tulang adalah 17.9 cm dan purata tulang fibula yang dipindahkan adalah 22.2 cm. Tulang allograf telah digunakan juga untuk 9 orang pesakit dengan purata panjang 19 cm.

Tiga (3) orang pesakit telah mengalami kecederaan pada saraf peroneal. Lain-lain komplikasi yang utama termasuklah koagulopati/DIVC (2 pesakit). Seorang pesakit mengalami penyumbatan pada salur darah yang tidak berjaya diselamatkan. Enam pesakit mula berpijak sepenuhnya dengan purata 27 minggu selepas pembedahan dijalankan. Tiga orang pesakit meningal dunia disebabkan oleh ketumbuhan yang merebak ke paru-paru, yang mana ianya tidak berkaitan dengan prosedur ini dan seorang lagi meninggal dunia seminggu selepas pembedahan di ICU disebabkan oleh septicemia.

Kesimpulan

Pemindahan tulang fibula bervaskular menawarkan kaedah yang berkesan dan boleh dipertimbangkan untuk memperbaiki semula defek yang besar pada tulang .Dengan menggunakan kaedah ini ,defek pada tulang panjang boleh diperbaiki dengan kadar yang segera , berbanding dengan menggunakan kaedah-kaedah yang lain. Kadar kegagalan dan komplikasi adalah masih rendah dan setara dengan pembedahan-pembedahan ortopedik major yang lain. Teknik pembedahan ini masih boleh diperbaiki dan dengan ini boleh mengurangkan komplikasi yang dialami.

Abstracts

Introduction

Skeletal defects following trauma or bone tumour resection may be successfully treated by conventional bone grafting or bone transport. However for massive defect following en bloc resection of a localized tumor , chronic osteomyelitis or following trauma ,the reconstruction of such defects is really challenging.

Vascularized fibular graft is one of the treatment alternative since 1975 when Taylor first reported the successful use of the graft for the reconstruction of a tibial defect. In Malaysia, vascularized fibular grafting for the management of massive bone loss is still new. Currently,this procedure has not been widely performed in Malaysia. In USM, A total number of 19 vascularized fibular graft had been performed involving various causes of bone defect and 13 cases involves the reconstruction of limbs within a period of 29 months.

Objectives

The objectives of this study is to assess the the outcome of using vascularized fibula graft for the reconstruction of massive bone defect and to analyze our own experience of the outcomes of the use of vascularized fibula graft for the reconstruction of massive long bone defect in combination with allograft or without allograft. The results will be compared with other similar studies that has been published. These include identifying the immediate complications of vascularized fibular grafting , to study the duration of time taken for the vascularized fibular graft to incorporate and time taken for the patient to start functional activities of the affected limb.

By the end of the study,we report a series of observations in a group of patients who had already undergone this very unique procedure . The observations were mainly focused on the outcomes of reconstruction of long bone defect using vascularized fibular graft technique.

Methodology

This is a descriptive and comprehensive review of thirteen patients using secondary data. There are two groups of patients in this study. The first group consisted of 9 patients who had undergone long bone reconstruction with combined vascularized fibula graft and an allograft. The second group consisted of 4 patients who had their long bone defect using vascularized fibula graft alone.All 13 patients had undergone reconstruction of the limbs following massive resection of the diseased bones. They were followed up and reviewed for the minimum of 6 months to see the early complications .Functional and radiological assessment were also done periodically.

Results

Thirteen patients had been operated for long bone defects reconstruction of various causes; tumor cases (9 cases) , infected non union that failed conservative treatment (3 cases) and congenital pseudoarthosis (1 case) .Patients age ranges from 2 years to 65 years old .The recipient sites involved 4 femurs, 7 tibias, 1 humerus and 1 radius and ulna. The total resection and reconstructive procedures take an average of 17.6 hours. All patient had undergone at least one operation prior to the surgery with the maximum had seven operations prior to it except the child with the pseudoarthrosis who was treated with this method primarily. An average skeletal defect reconstructed is 17.9 cm in length and the average fibular graft harvested is 22.2 cm in length. Allograft used in 9 patients with an average length of 19 cm.

Three (3) patients developed common peroneal nerve injury. Other major complications include coagulopathy/DIVC (2 patients). One patient developed an unsalvagable vascular trombosis and total flap loss. Six patients have started full weight bearing with an average of 27 weeks post operatively. Two died due to secondaries to the lungs, not related to the procedure,and the other died one week post-operative day in ICU due to septicemia which is directly related to the procedure.

Conclusion

Vascularized fibular grafts offer an effective and considerable mean of reconstruction of a segmental massive bone defect following en-bloc resection for various indications. Using this procedure, the long bone defect can be reconstructed and the length loss can be corrected almost immediately and immediate revascularization did improve the outcomes, compared to other surgical procedures. The failure and the complication rates are relatively low and comparable with other major orthopedic procedures. Surgical technique can be improved thus minimizing the complications.

1. Introduction

Skeletal defects following trauma or bone tumour resection may be successfully treated by conventional bone grafting or bone transport which include Papineau graft, allograft and the use of Ilizarov method. However for massive defect following en bloc resection of a localized tumor, chronic osteomyelitis or following trauma ,the reconstruction of such defects is really challenging.

1.1. Papineau graft

Autologous cancellous grafting had been used for the management of bone defect for a long time. This tissue tolerate low grade contamination; indeed such grafts are often used to fill osteomyelitic cavities.(Green & Ripley,1984)

Unfortunately the small number of donor sites in the human body constitute an absolute limit on the quantity of fresh autologous cancellous bone available for filling of segmental defects. Certain locations - the anterior iliac crest, the greater trochanter , the distal femur - provide bone graft which is enough to fill an osseous defect of approximately 2 cm in length only. Even four donor sites at once, providing enough material to fill a defect up to 8 cm long. However, a graft mass of this size may take a long time to fully corticalize and support a superimposed body weight load.(Green,1994) .As Weiland et. al. discovered, early fracture of the transplanted bone -either fibula or iliac crest was a common problem. Large volume of bone needed to fill a defect greater than 6 cm required multiple donor sites and this becomes a source of discomfort and morbidity for the patients.(Green & Diabal, 1983)

1.2.Ilizarov method

Ilizarov's technique of bone transport was considered as the ideal solution for large skeletal defect because of many reasons. A defect of virtually any size could be eliminated without limb shortening and by using this technique, no donor site morbidity would occur because the need for bone grafting had been eliminated. However still, this method shared several problems such as pin tract infection, dermatitis, proximal and distal joint stiffness, joint deformity, compartment syndrome, nerve palsy, reflex sympathetic dystrophy , contracture and non union. Other problem related to the equipment include broken wires and of course it also depends on the surgeon's learning curve.(Velazquez et.al.,1993)

1.3.Allograft

Allograft is popular among the tumor surgeon for reconstruction of large bone defect .Either one of the three types of allograft bone can be used for reconstruction. However, infection is the principal complication of implantation of allograft.(Mankin et.al.,1983, Mnaymneh et.al.,1985, Lord et.al.,1988 & Tomford et.al.,1990) The rate of infection approaches 12 % (Mankin et.al.,1983 & Lord et.al.,1988) and considered higher than other orthopedic operations. Furthermore the management of allograft infection is very difficult. Resection of the allograft or amputation of the affected limb are considered a failure. Apart from infection, other problems or disadvatages associated with allograft are allograft fracture,(Dick et.al., 1985 & Griend, 1994) extremely slow revascularization ,thus incorporation (Newington & Sykes,1991) and risk of transmission of diseases like AIDS (Nemzek et.al., 1994) ,Hepatitis B (Mankin et.al.,1983) and osteomyelitis as well.

1.4.Vascularized fibular graft.

Vascularized fibular graft becomes one of the treatment alternatives since 1975 when Taylor first reported the successful use of the graft for the reconstruction of a tibial defect.(Taylor, 1975) Since then many other reports followed.(Weiland et.al.,1983, Harrison, 1986, De Boer & Wood, 1989, Jupiter et.al., 1997, Moore & Weiland, 1986, Gordon et.al.,1986 & Minami et.al.,1997).

The first description of its use after resection of bone tumour was reported by Weiland et. al. in 1981.(Weiland, 1981)

In Malaysia, vascularized fibular grafting for the management of massive bone loss is still new. However this technique is slowly becoming more and more popular especially in Hospital USM, Kubang Kerian. The first reconstruction surgery involving vascularized fibular graft was first done in 1997. Since then this hospital received more and more referrals from other hospital all over Malaysia. Since 1997,a total number of 19 free vascularized fibular graft had been performed involving various causes of bone defect of the limbs. At the moment reconstructive surgery involving this technique is not done in other general or university hospitals as frequent as in this hospital because of various reasons. It is not only technically demanding but also because of the availability of other treatment alternatives.

So with the limited number of cases that are available in this hospital , it is hoped that the results that are gained from this study can be shared and the limitations of this technique can be discussed and improved in the future. It is hoped that this technique will be expanded and made available in other hospitals as well for a better standard of patient's care.

2.Literature Review

2.1.Vascularized fibula graft

2.1.1.Anatomy of the Fibula

The anatomy of the fibula and its vasculature has been described in details by Yun et.al. (Yun & Qi, 1994)

Fibula is not the main weight bearing bone of the leg. Its upper three quarters only serve to give attachments to the adjacent muscles. Therefore, removal of this segment of the shaft has no significant effect on the weight carrying and the stability of the leg, That is why the bone has been taken as a suitable donor for both conventional and microvascular bone transplantations.

2.1.2.Morphologic and functional characteristics of fibula

Fibula, the most slender of the long bones in the skeleton is almost perfectly cylindrical in the greater part of its extent and situated at the lateral side of the leg. It is 34cm in length and 3cm longer in male than in female. Its upper extremity, the head, is expanded, presenting above a flattened articular surface directed upward and medially for articulation with a corresponding facet on the lateral condyle of tibia. It also bears a surface, superomedially, for the attachment of the ligament of fibular head. The articular cavity of fibulotibial joint does not communicate with that of the knee joint. The long slender shaft of fibula is described as having four borders and four faces. The anterior border begins above in front of the head, runs vertically downward to the lower segment of the bone and then bifurcate so as to embrace a triangular surface immediately above the lateral malleolus. The posterior border is situated laterally behind the anterior border, while the anteromedial border or the interosseous crest is situated medially behind the anterior border. The medial border lies between the posterior and the anteromedial borders. The lateral surface is the interval between the anterior and the posterior borders. It is directed lateralward in the upper two thirds of its course, the upper half of which is extremely narrow and flat and the lower grooved longitudinally, and backward in the lower third, where it is smooth and broader and continuous with the lateral malleolus. The anterior surface gives attachment to the peroneus longus and brevis.

The posterior surface is the space included between the posterior and the medial borders. It is directed backward in its upper part for the attachment of the soleus; while its lower part gradually turns medialward for the attachment of the flexor hallucis longus. The medial surface is the interval included between the middle and the antero-medial borders. It is grooved for the attachment of tibialis posterior. The anterior surface is the space between the antero-medial and the anterior borders. It is smooth and broad in the upper part and narrow in the lower part. It is directed medialward and gives attachment to extensor hallucis longus, extensor digitorum and peroneus tertius. Although it is simple and convenient to regard the shaft of fibula as having four borders and four faces for describing the attachment of the muscles to the bone and understanding the physiologic functions of different groups of the muscles, it should be emphasized that there are some morphologic differences of fibula in different individuals. In some cases, for example, the cross section of fibula is almost oval in shape, while in others it is triangular. The lower extremity is also called the lateral malleolus. Its medial surface is triangular, which articulates with a corresponding surface on the lateral side of talus, while the lateral surface is convex and subcutaneous. The anterior border gives attachment to tibiofibular ligament, anterior lateral malleolar ligament and calcaneofibular ligament. The posterior border is broad and transmits the peroneus longus and brevis. Since the lateral malleolus constitutes the lateral wall of glenoid cavity of the ankle joint and its anterior and posterior borders afford attachments for the ligaments mentioned above, it plays an important role in maintaining ankle stability

2.1.3.Nutrient foramen

Cases with one foramen are the commonest (90%), the next are those with two foramen (8%), those with more than three are uncommon (2%). The diameter of the foramen averages 0.5mm. Most of them are located in the middle segment of the shaft.

2.1.4.Blood supply

Similar to other long bones, fibula is supplied by nutrient artery, epiphyseal arteries and periosteal arteries .Blood supply to the fibula comes mainly from the peroneal artery, which nourishes the bone by sending branches, i.e. the nutrient artery and the arcuate arteries, to the marrow cavity, the periosteum and the cortex of the bone. The peroneal artery arises from the posterior tibial artery, 2.9cm on the average below the mid-point of the lower border of popliteus muscle. Its average outer diameter is 4.0mm. The artery proceeds laterally downward, keeping at first some distance from the fibula. The further distal

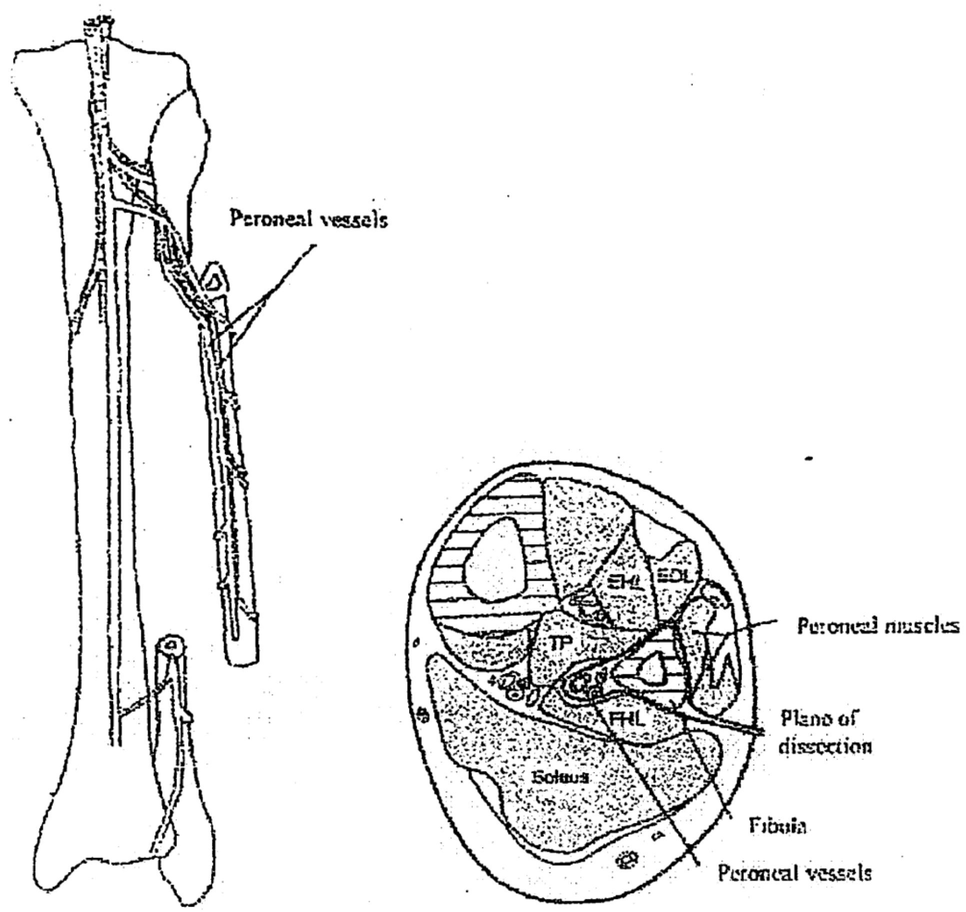

Figure 1. Free vascularized fibula graft isolated on peroneal vessels (Rouholamin,1994)

it proceeds the nearer it approaches the bone. Hence, the upper segment of the artery can be exposed by cutting the posterolateral intermuscular septum between the peroneus longus and soleus muscles along the lateral border of fibula and pulling the soleus muscle aside. The lower segment of the artery, that is the lower three-fourths, is covered by flexor hallucis longus. Sometimes, the muscle arises so high and is developed so well that the whole length of peroneal vessel is covered by it. In such case, it is necessary to incise the muscle along its medial border so as to expose the vessel. The peroneal artery can be divided into four types.

Type 1, or the posterior tibial artery type: This type of the artery amounts to 90%. The artery originates from the posterior tibial artery. It approaches the fibula gradually after its commencement and then proceeds downward along the bone.

Type 2, or the anterior tibial artery type: The artery arises from the anterior tibial artery at the level 4.7cm below the head of the fibula. This type represents 1 %.

Type 3, the popliteal artery type: This type also represents 1 %. The artery comes from the popliteal artery 3.3cm from the head of fibula.

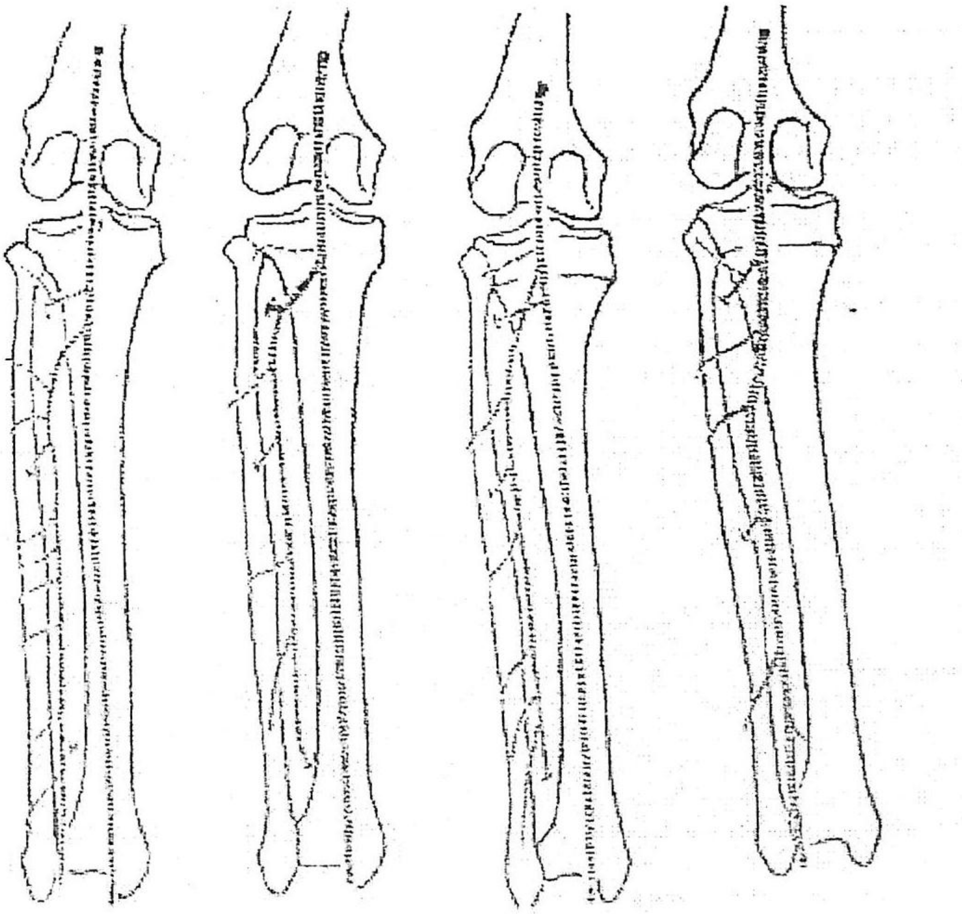

Figure 2. Diagram shows the origins of peroneal artery (Yun & Qi, 1994)

Type 4, This is a special type. The posterior tibial artery is absent and replaced by peroneal artery completely. The peroneal artery courses at first through the way similar to Type 1, and then turns medially above the ankle joint and passes to the plantaris through the bifurcated ligament.

The nutrient artery of fibula arises from the peroneal artery at the level 7.9cm below its origin. It is 1.6cm long from Its origin to the foramen and its outer diameter at its commencement averages 11.0mm. It proceeds laterally downward between flexor hallucis longus and posterior tibialis and then enters the bone through the foramen. It gives, on the way branches to the flexor hallucis longus and fibular periosteum and after penetrating the bone, it divides into an ascending and a descending branch. The ascending branch again gives off many secondary branches to the bone, and its terminal branch anastomoses with the epiphyseal vessels at the upper extremity of the bone. The descending branch also gives many secondary branches to the bone and its final branch anastomoses with epiphyseal vessels at the lower extremity.

The arcuate arteries, about 9(4-15) in number, are relatively small, with an average outer diameter of 1.0mm. The origins of the arteries are not constant. The first and the second arcuate arteries may be derived from popliteal, anterior tibial, posterior tibial or peroneal arteries; while the others all come from the peroneal artery. The arcuate arteries anastomose with each other forming a profuse peroneal network on the surface of fibula.

The peroneal veins, usually two in number, course on either side of peroneal artery and collect, on their way, venous branches accompanying the parallel arteries. They empty into posterior tibial vein about 2.1cm from the lower border of popliteus, with an average outer diameter of 4.2mm, slightly larger than the accompanying artery.

There is no obvious difference between adult and child in respect to the source of blood supply to the fibula, only the blood vessels of fibula are relatively smaller in children. In one year old children, the outer diameter of peroneal artery averages 1.0mm, while in the children of three years old, the vessels of fibula have an outer diameter above 1.0mm. The largest may reach 2.0mm.

2.1.5. Applied anatomic essentials

A straight length of 22-26cm, or the whole length of the upper three quarters of fibula is available for grafting; while the fibular head, which bears an articular facet is usually used for the reconstruction of radiocarpal joint.

The distal quarter of the bone should be retained for ankle stability. Blood vessels crucial to successful fibular transplantation are the peroneal vessels rather than the nutrient artery. It has been demonstrated clinically, that provide the peroneal artery as well as its periosteal branches are preserved, blood supply to fibular graft may be assured, even though the nutrient artery is excluded from vascular pedicle. Therefore, either the fibular bone or the fibular periosteal flap should be designed on its peroneal blood supply. The most vulnerable structure during the dissection of donor bone is the common peroneal nerve and its branches below the fibular head. It is preferable to identify these nerves first during the dissection so as to prevent them from being injured. Precaution should be taken in separating the tibiofibular joint to make sure not to damage the anterior tibial vessels which penetrate the interosseous membrane posteriorly below the joint.

The periosteal artery can be divided into four types with regard to its origin. In the first three types (type 1, type 2 and type 3), the dorsal aspect of the leg is supplied by two vessels coming from different sources, while in type 4, only one vessel is available. It has been demonstrated in the clinical practice, that after the excision of the unique vessel of the dorsal aspect of the leg, blood supply to the foot can be replenished by the common trunk of the anterior tibial artery. However, for caution's sake in such case, temporal ligation of the peroneal artery should be carried out before taking the artery as a pedicle vessel, to make sure that blood supply to the foot will not be disturbed. There has been little follow-up serving data so far to conclude if the fibular transplantation has any significant effect on the function of ankle joint It is believed generally, that in adult, removal of fibular shaft will produce little functional change of ankle joint. But in childhood, when epiphysis at the lower extremity is still developing and the bone is growing, removal of the shaft may result in the shift of epiphyseal line, which in turn leads to the disturbance of the function of ankle joint. Hence, it is suggested that at least the lower one-quarter or one-third of the shaft should be retained, and when necessary, rigid skeletal or screw fixation should be used for ankle stability.

2.1.6. Surgical technique

Surgical technique for free vascularized fibular graft has been detailly described by Weiland et. al. as follows. The surgical technique are also described by other authors. (Harrison, 1986 & Jupiter et.al., 1997)

The artery of the fibula arises as a branch of the peroneal artery, which originates from the posterior tibial-peroneal trunk. The peroneal artery gives rise to several periosteal branches before the artery that supplies the medullary flow to the fibula. Penetration through the fibular cortex usually occurs at the mid-diaphysis level, with a variation of 2.5 cm proximally or distally. The peroneal artery continues distally along the medial and posterior aspects of the fibular diaphysis and provides direct musculoperiosteal branches. Therefore, preservation of the medullary and periosteal blood supply to the fibula is possible by isolating the peroneal artery at its origin, the posterior tibial-peroneal arterial trunk .

To facilitate a description of the dissection technique, fibula harvesting has been divided into eight steps. The procedure is performed with the patient supine and the donor knee flexed approximately 135 degrees. The surgeon and first assistant stand lateral to the leg with the second assistant sitting medially, supporting the flexed extremity. A tourniquet is used during the dissection.

Step 1. A straight lateral skin incision is made along the line of the fibula extending from the neck as far distally as needed. The incision is carried through the skin and sub-cutaneous tissue to the fascia overlying the peroneus longus muscle.

Step 2. The anterior and posterior flaps are elevated as needed, to identify the interval between the peroncus longus and soleus muscles. The deep fascia is then incised along this interval, the entire length of the wound. The fibula is palpated periodically during the dissection. Using a blunt elevator, the interval between the peroneus longus and soleus muscles is developed. Using an extraperiosteal dissection technique, the peroneus longus and soleus muscles are reflected from the fibular diaphysis anteriorly and posteriorly, respectively.

Step 3. The lateral border of the fibula is exposed. If skin is to be harvested with the fibula, the three perforating vessels to the skin lying immediately posterior to the fascia and overlying the soleus muscle must be

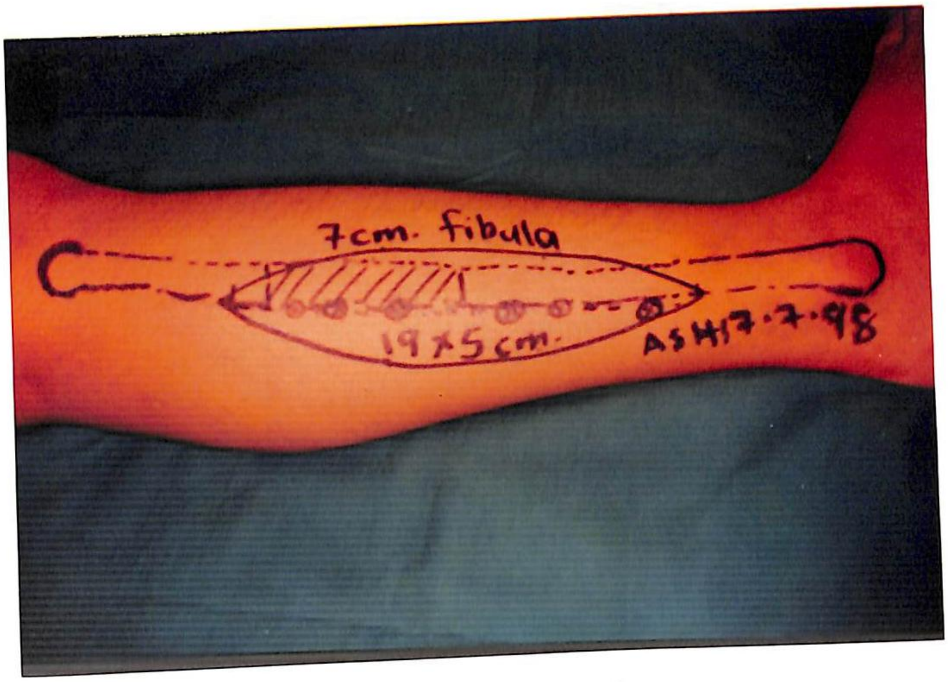

Figure 3. Preoperative design of vascularized fibula graft with skin paddle.

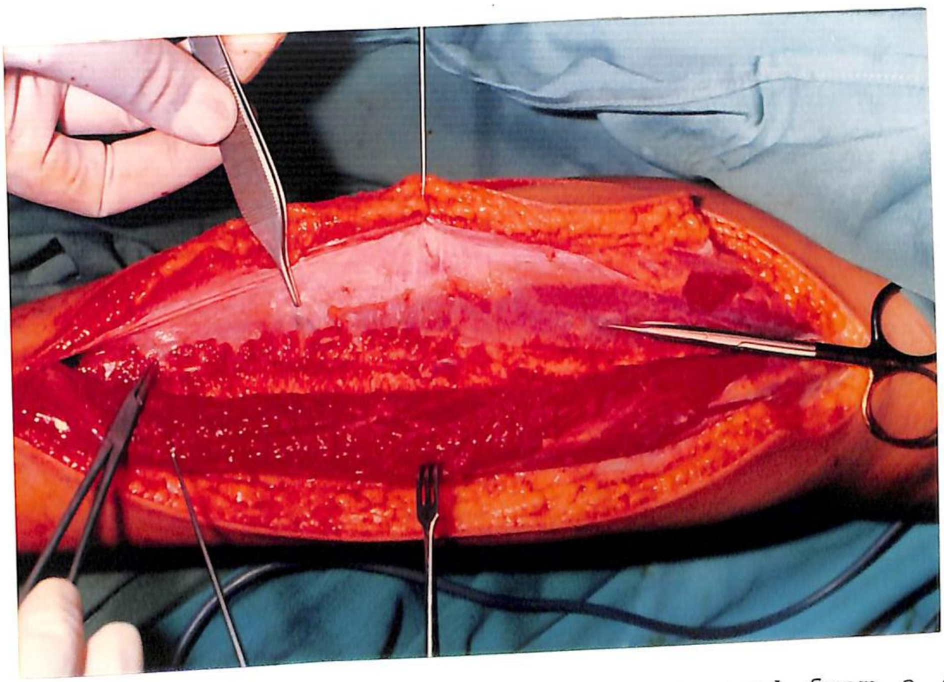

Figure 4. A fibula graft after being exposed from a donor site.

preserved. When the bone alone is to transferred, these vessels should be ligated.

Step 4. Beginning proximally and using a blunt elevator, the peroneus longus and brevis muscles should be elevated from the lateral border of the fibula until the anterior crural septum is reached, staying close to - bone. The anterior crural septum is then divided, and the extensor muscles (extensor digitorurn longus, peroneus tertius, and extensor hallucis longus are dissected from the interosseous membrane. The dissection continues until the anterior tibial artery and nerve have been identified and protected.

Step 5. The posterior crural membrane is divided along the entire length of the graft. Using careful extraperiosteal dissection techniques, the soleus and flexor hallucis muscles are reflected off the posterior border of the fibula. The dissection continues until the peroneal vessels are encountered. They must be left attached to the posterior surface of the intermuscular septum, and any branches arising must be coagulated. Dissection is continued anteriorly and posteriorly for the length of the graft required. Special

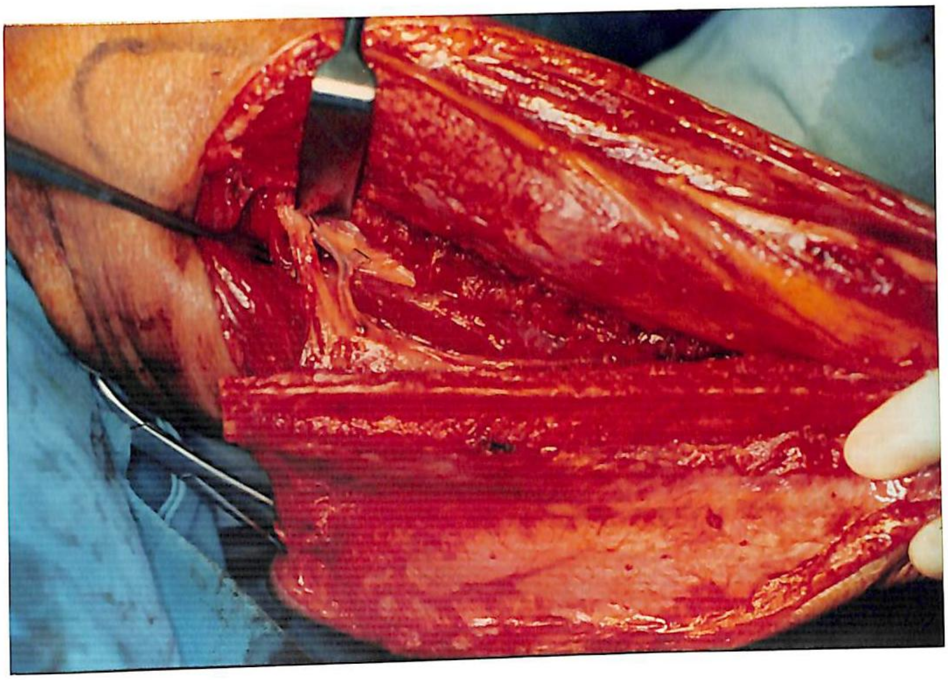

Figure 5. A section shows peroneal artery and veins that are the main feeding vessels for the fibula graft.

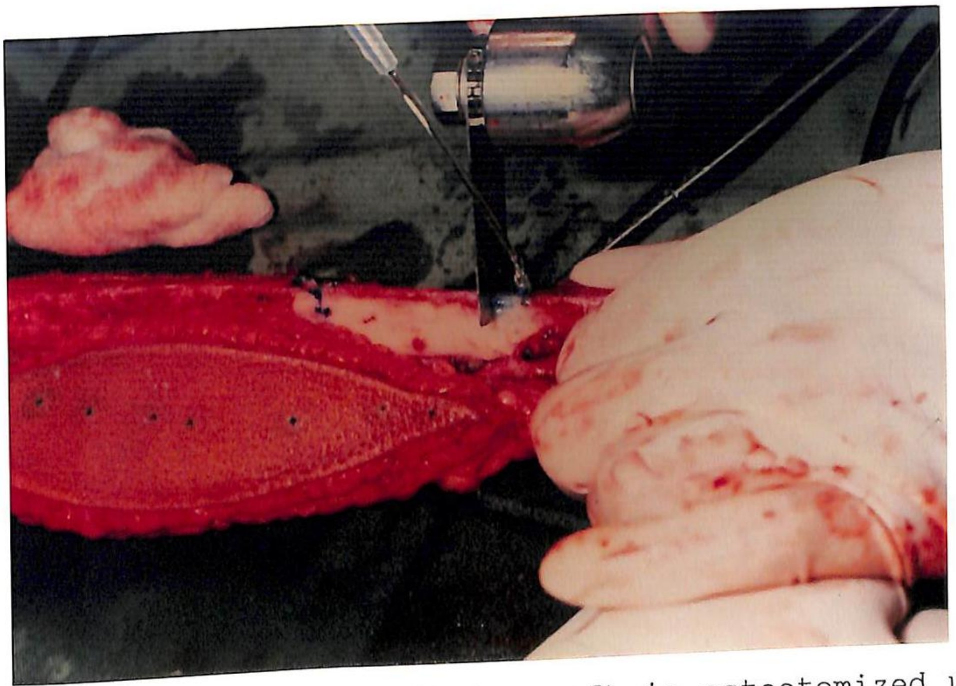

Figure 6. A vascularized fibula graft is osteotomized using an osteotome during the preparation of a vascularized fibula graft.

care is needed not to damage the peroneal artery, which, in the distal one third of the fibula, lies directly on the posterior surface of the bone.

Step 6. The length of graft needed is measured and marked with methylene blue. All attempts should be made to preserve the distal 6 cm of the fibula, to maintain the integrity of the lateral aspect of the ankle joint. If distal dissection is required in a child, a transfixion screw will preserve the integrity of the ankle mortise and prevent possible proximal migration of the distal fibula. At the site of the distal osteotomy, the peroneal vessels must be pushed medially from the intermuscular septum. A hole is made in the septum sufficient to allow a 2.5-cm malleable retractor to be placed around the bone, protecting the vessels that lie posterior to the retractor. A Gigli saw may be used to cut the bone and the distal osteotomy performed. A similar procedure is carried out at the proximal end of the graft. The distal limb of the peroneal artery and veins are then ligated at the site of the distal fibular osteotomy.

Step 7. A small bone hook in the medullary canal of the distal portion of the fibular graft is used to stabilize the fibula during the remaining dissection. The graft is retracted posteriorly, and the interosseous membrane is divided along the entire length of the graft. The graft is then carefully retracted anteriorly, and the tibialis posterior is dissected distal to proximal from the posterior middle one-third of the graft, where it has remained attached to the fibula.

The fibula is retracted anteriorly or posteriorly, as needed, to leave the fibular graft isolated on its vascular pedicle proximally.

Step 8. The surgeon traces the peroneal artery proximally to its junction with the posterior tibial artery. A vessel loop is placed around the peroneal artery and vein. The fibula is then placed back into its bed, where it remains until the recipient site is prepared. The tourniquet is deflated. When the dissection in the recipient bed is completed, the fibula is harvested and placed into the defect. After stable fixation is achieved, microvascular anastomoses of the peroneal artery and vein to recipient vessels are performed.

The average operative time taken for vascularized fibular graft is 7 to 8 hours. (Weiland et.al., 1983 & Hsu

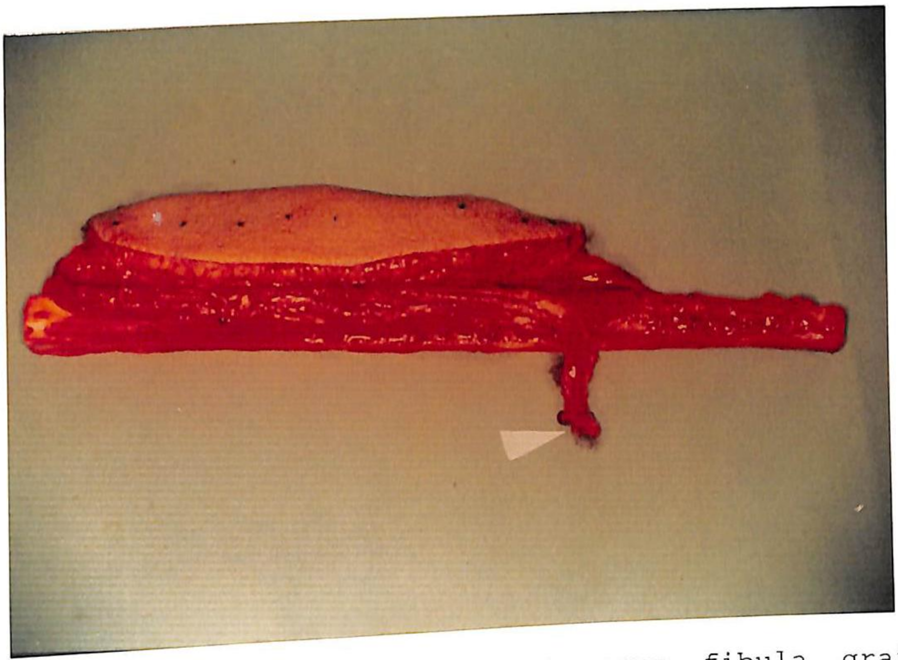

Figure 7. A vascularized osteocutaneous fibula graft, after being resected from the donor site. An arrow shows the feeding vessels to the fibula graft.

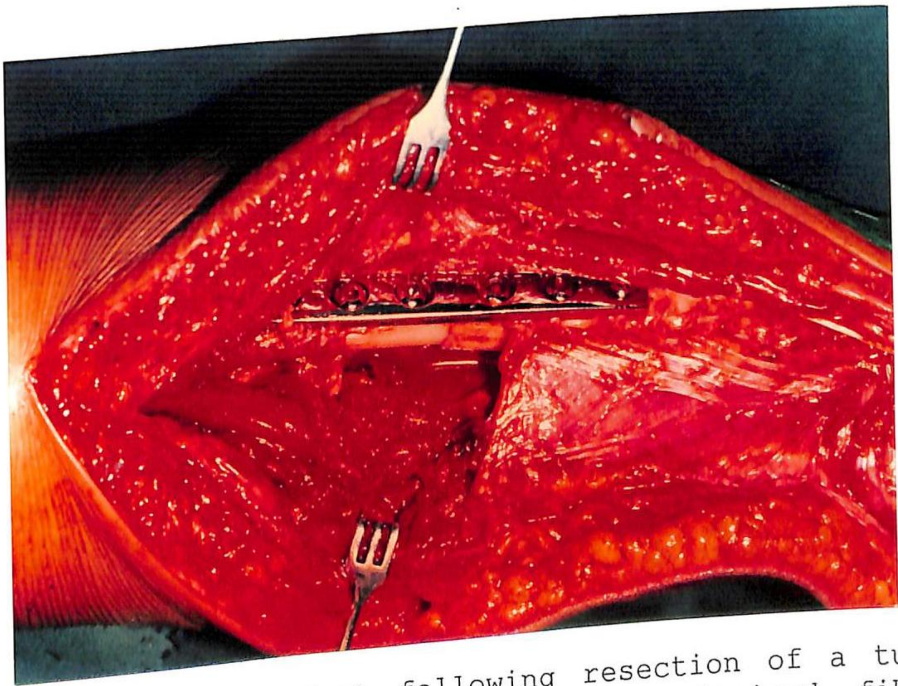

Figure 8. Skeletal defect following resection of a tumor from a radius, reconstructed with vascularized fibula graft.