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Review Article

FLAPS IN LOWER LIMB TRAUMA: CURRENT STATUS

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The importance of obtaining early definitive wound healing after lower extremity trauma cannot be over emphasized. The restoration of an intact covering is the primary surgical requisite following trauma of the lower extremity because deep healing can be no better than the surface covering[1].

The history of plastic surgery in the lower extremity is predominently that of lower extremity trauma, particularly inflicted during war time. Better understanding of muscular anatomy, cutaneous blood supply, and microsurgery have made tremendous advancement in the field of lower extremity reconstruction.

The concept of emergency free tissue transfer[2] was developed in 1980. Organisation of a continuous joint orthopedic - plastic surgery service is necessary to offer patients the option of a single stage operation that combines debridement and eventual final reconstruction. There will always be sporadic cases in which delayed primary reconstruction is preferred for medical reasons, but practicing it for convenience should be eliminated.

Anatomy

Following unique features of the lower limb makes the reconstruction different from that for the upper extremity[2]:

1) The lower extremity is almost always in a dependent position and more susceptible for deep vein thrombosis, venous stasis and oedema.

2) Increased incidence of peripheral vascular diseases.

3) The subcutaneous location of the tibia, the main weight bearing bone of the leg, poses unique problems in the fracture healing.

Principles

I. ***Vascularity of the limb*** should be checked at the earliest.

II. ***Assessment of the defect and structures exposed:*** The defect is assessed for soft tissue and bony loss. The exposed structures like bare tendon and bone alters the management strategy.

The " Gustilo-Anderson" classification of open leg wounds [3,4] is as follows.

Grade I
Wound less that 1cm long, clean, little soft tissue damage, no crush injury.

Grade II
Laceration greater that 1cm, no extensive soft tissue damage; no flaps or skin avulsions and moderate skin crush.

Grade III
Extensive soft tissue damage, including skin, muscle and neurovascular structure; highly contaminated. Further divided into 3 groups:

a) Large Laceration or skin flaps that nevertheless provide for adequate soft tissue coverage

b) Extensive loss of soft tissue with periosteal stripping and exposed bone; massive contamination, severe communition and loss of bone

c) Open fracture associated with arterial injury requiring repair

The classic reconstruction ladder (primary closure, skin graft, flap) is helpful but is not the sole criterion used for planning reconstruction in cases of lower limb trauma.

III. ***Assesment of the region involved:*** Reconstruction of the lower extremity has traditionally been planned by dividing the leg in three parts. Flaps avilable in each third are then enumerated (eg. Gastrocnemius for the proximal third, soleus for the middle third, free tissue transfers or distally based flaps being reserved for the lower third of the leg). Although this traditional method can be useful, the surgeons must decide what is the optimal technique for the particular defect, not necessarily the most expeditious.

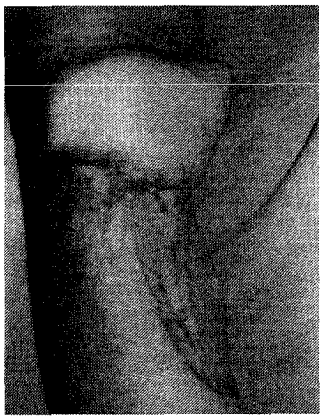

Fig 1. Defect over anterior aspect knee covered with Superiorly based fasciocutaneous flap. Donor area was skin grafted.

I. SOFT TISSUE COVERAGE OF THE LEG DEFECTS

The time honoured concept of dividing the lower leg into three parts and deciding the type of pedicled flap required, remains useful, but must be subordinated by a more functional and aesthetic evaluation of the wound.

A) Skin grafts

Skin grafts are applicable only if there is a healthy vascular recepient bed or if the periosteum over the bone is intact.

B) Skin flaps

Local skin flaps like transposition, rotation and local advancement flaps are suitable only for small defects. Islanded skin flap from dorsum of foot (based on dorsalis pedis vessels) may be used for defects around ankle joint including over malleoli and tendoachilles. Distant skin flaps like cross leg flap, abdominal tube pedicle flap and jump flap have become almost obsolete as they are staged procedures and are indicated for larger defects.

C) Fasciocutaneous flaps

Fasciocutaneous (FC) flaps (Fig 1) have been well investigated and tried out in the leg defect.As early as in 1901, Pouteau[5] reported the use of fasciocutaneous flaps in the lower leg. Taylor's work on the blood supply to the skin demonstrated that in the trunk it is usually musculocutaneous and in the limbs fasciocutaneous in nature. Ponten[5] had shown that the flaps in the leg can measure 8cm x 18cm and can be raised in a single stage without necrosis if the deep fascia is included. FC flap may be used locally in the ipsilateral limb or distally as a cross leg FC flap.

The blood supply to fasciocutaneous flaps can be from three sources[6].

1) Musculocutaneous perforators: For example via gastrocnemius

2) Axial vessels: Sephenous artery and superficial sural arteries

3) Septocutaneous perforators: For each of anterior tibial, posterior vessels tibial and peroneal vessels

Numerous authors have attempted to study the location of septocutaneous perforators in relation to bony land marks and leg lengths (Table 1).

Advantages of FC flaps

1) One stage procedure
2) Simple to execute
3) Gives a stable cover
4) If required, a portion of the flap can be deepethelized to obliterate a cavity
5) The flap can be islanded

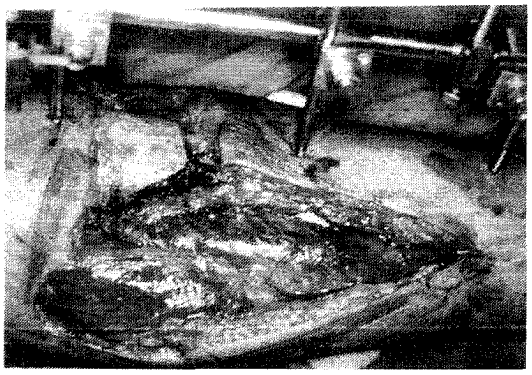

Fig 2a. Grade III compound fracture of upper $^{1}/_{3}$ of tibia with exposed bone

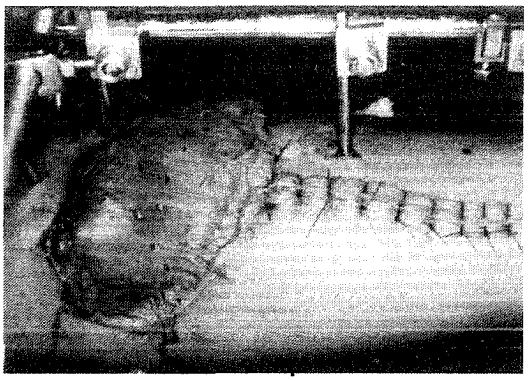

Fig 2b. Same patient treated with gastrocnemins muscle flaps. The exposed muscle surface was covered by skin graft

Table 1. Location of Septocutaneous perferators [6,7]

Vessels ⟶ / Location ⟶ ↓	Posterior Tibial (Distance from MM*)	Peroneal Distance from LM* or FH*)	Anterior tibial
N 1	4.5cm.	4 -10cm (LM)	2-4cm from the origin of Anterior tibial artery
N 2	6.0cm.	10 - 13cm** (LM)	
N 3	9 - 12cm**	15 - 20cm** (LM)	
N 4	17 - 19cm**	5 - 6cm (FH)	
N 5	22 -24cm**		

* LM = Lateral malleolus, FH = Fibular head, MM = Medial malleolus,
** Constant locations of fasciocutaneous vessels.

Disadvantages of FC flaps

1) Donor site needs to be skin grafted,

2) Unlike muscle flap, not suitable for filling infected cavities.

Selection of fasciocutaneous flaps for leg defects

a) Knee and upper third leg

Proximally based fasciocutaneous flap based on the perforators of the post tibial, anterior tibial [5,6,7] or peroneal artery [5,6]

b) Middle third leg

Proximally based flaps on the posterior tibial or peroneal perforators [5,6,] or a distally based flap on the lower posterior tibial perforators[8].

c) Lower third leg

Distally based or cross leg fasciocutaneous flap may be used

- Flaps based on Lower perforators of the post tibial and peroneal arteries [8,9]
- Reverse sural artery flap[10,11]
- Posterolateral malleolar flap[12]
- Distally based fasciocutaneous flap

D) Adipofascial flaps

Adipofascial flaps have become extremely popular in the last decade in the reconstruction of lower leg defects. Adipofascial flaps are like fasciocutaneous flaps, as the vascular basis is same in both flaps. Gumener [13] described distally based fasciosubcutaneous flap to recon-

struct soft tissue defects of lower leg and foot. Lin etal [14] popularized the distally based medial adipofascial flaps to cover the exposed bones in the lower leg. These flaps are ideal for reconstruction of composite defects around the lower leg and ankle. Flaps are based on the posterior tibial, peroneal, anterior tibial vessels and their perferators. The flap once placed over the defect always needs to be covered with skin graft.

The basic advantage of adipofascial flap over fasciocutaneous flaps is that it carries least donor site morbidity as the donor site can be closed primarily.

E) Muscle and musculocutaneous flaps

In 1981 Mathes and Nahai[15,16] described the classification and clinical application of muscle and myocutaneous flaps. In the lower extremity, local (Gastroenemius [17,18,19], Soleus[20]) or distal (as microvascular transfer of gracilis[21], Latissimus dorsi[22,23,24,25] rectus abdominis[26] muscle or musculocutaneous) flaps are available (Fig 2a, 2b).

The muscles useful for coverage of post traumatic leg defects and the region where their use is recommended include the following:

Proximal third leg defects

- Gastrocnemius [17,18]
- Skin fascial gastrocnemius

Middle third leg defects

- Soleus[20]
- Flexor digitorum longus[15]
- Peroneus longus[15]
- Tibialis anterior[15]
- Extensor digitorum longus[15,16]

Distal third leg defects

- Soleus[20]
- Tibialis anterior[16]
- Extensor hallucis longus[16]
- Peroneus brevis[16]

F) Free flaps

In 1973, Daniel and Taylor[27,28] reported the free transfer of groin skin and subcutaneous tissue by use of microvascular anastomoses. commonly used free fasciocutaneous flaps are radial artery forearm flap[29], dorsalis pedis flap[30], scapular[31], parascapular[32], lateral arm flap[33], and posterior calf fasciocutaneous flap[34]. Muscle and myocutaneous free flaps commonly used for lower limb reconstruction are latissimus dorsi (Fig 3,4) gracilis[21], tensor fascia lata [35,36] and rectus abdominis[26] (Fig 5) flaps.

Fig 3a. Post traumatic defect over ankle and foot with exposed bone and joint.

Fig 3b. The ankle defect covered with free latissimus dorsi muscle. The exposed muscle was covered by split skin graft.

Fig 4a. Defect over anterior lateral aspects of knee with exposed joint following high voltage electrical injury.

Fig 4b. The knee defect covered with latissimus dorsi muscle flap. The exposed muscle surface was covered with split skin graft.

Composite osteocutaneous free flaps[37] used for one stage reconstruction are radial artery osteocutaneous flap, fibula flap[37] and deep circumflex osteocutaneous free flap[37]. It is usually the Grade IIIb fractures of the legs, and the avulsion and crush injuries of the foot that need free flap cover. The basic objectives in these situations are:

a) Good and early healing of bone

b) Good movement of contiguous joints

c) An aesthetically acceptable stable cover

II. SOFT TISSUE COVERAGE OF THE FOOT DEFECTS

The unique anatomic and functional characteristics of the foot merit special consideration.

It is convenient to divide the foot in to the following regions:

1. Malleoli, achilles tendon and nonweight bearing posterior heel
2. The heel and mid plantar area
3. Distal plantar area
4. Dorsum of the foot

The choice of the procedure for soft tissue coverage largely depends on flaps available in that area and whether or not the area is weight bearing portion of the foot. To some extent it depends on factors like availablity of trend personnel, facilities and overall general picture (general condition, age, other medical illness) of the patient.

Fig 5a. Supramalleolar defect over the lateral aspect of leg with a cavity in the exposed bone.

Fig 5b. The cavity was filled with free transerve abdominis muscle flap. The exposed muscle surface was covered with split skin graft.

Types of Foot Injuries

Type I - Limited soft tissue injury; tendon and bone not exposed.

Type II - Major soft tissue loss over non weight bearing area or distal weight bearing area with exposed/damaged tendons, bones or forefoot/ toe(s) amputation(s).

Type III - Major soft tissue loss over/extending over proximal weight bearing portion of foot (heel and proximal sole) with or without fracture of calcanium and talus.

The ideal reconstruction provides sensibility, stability and satisfactory appearance.

Options for wound cover

A) Skin grafts

Skin graft is the method of choice when adequate soft tissue padding is present.

B) Skin flaps

Local skin flaps as rotation (Fig 6a, 6b), transposition or advancement flaps are suitable only for small defects. Axial innervated skin flaps are methods of choice for weight bearing areas[38]. Distant skin flaps as tube, cross leg, cross thigh or cross foot flaps are of only historical interest.

C) Fasciocutaneous flaps

For Larger defects, flaps that include the medial plantar artery either as axial pattern flap or fasciocutaneous flap are recommended[38,39]. The entire non weight bearing portion of the midfoot can be raised to reconstruct the soft tissue defects over heel.

The Lateral calcaneal artery fasciocutaneous flap can be employed either as a transposition flap or as an island flap to cover the achilles tendon and posterior non weight bearing heel.

D) Muscle and myocutaneous flaps

Flexor digitorum brevis muscle[38] and skin graft is an alternate flap for heel coverage. Abductor hallucis muscle with skin graft is an alternate flap for defect below medial malleolus[38].

Abducterdigiti minimi muscle[38] with skingraft is used for defects below lateral malleolus.

E) Free Flaps

Free tissue transplantation can cover extensive defects of foot when a local innervated flap is not available.

The temporoparietal fascia free flap[40] provides thin cover over the achilles tendon. Other free fasciocutaneous flaps commonly employed are radial artery[29] forearm flap and dorsalis pedis[30] flap. Small free muscle flaps[41] are ideal for coverage of the malleoli; they are more reliable and involve less morbidity than attempts to stretch a local muscle flap from the sole of the foot to reach the malleoli.

It has been demonstrated that stable coverage is obtained with skin grafted free muscle flaps[41] (gracilis, latissimuse dorsi) on the sole of the foot. The more mobile tissue that accompanies a muscutocutaneous or fasciocutaneous free flaps makes the skin island less stable and causes more problems than a skin grafted free muscle flap.

Conclusion

First and foremost goal in the management of limb injuries should be to check and establish satisfactory circulation. Then, having assessed the defect in the context of the individual patient, the surgeon must project what the ulti-

Fig 6a. Chronic ulcer over sole

Fig 6b. Ulcer was excised and covered with a rotation flap.

mate function of that extremity will be and plan the sequence of therapeutic steps to yield that result. If such planning does not begin at the initial evaluation, multiple poorly organised procedures may result in an amputation that could have been parformed safely after the patient was first seen, sparing the patient (and the surgeon) considerable frustration. The classic reconstruction ladder is useful but is not the sole criterion for planning a reconstructive procedures. A sensate flap for weight bearing areas is desirable.

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