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A Suggested Algorithm for Post-Traumatic Lower Limb Soft Tissue Reconstruction

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ABSTRACT

The evolving technology in trauma management today permits salvage of many severe lower extremity injuries previously even considered to be lethal. The role of different reconstructive options in lower extremity injuries has been reviewed in 100 patients. The frequency of use of reconstructive techniques, specific complications and benefits, effect of timing of wound closure, and rate of limb salvage were compared. The ages of the patients ranged between 3 and 66 years with a mean age of 19.76 years. 54 cases were with simple wounds with no exposed bone, tendons or neurovascular structures while 46 cases were with complex wounds with exposed bone, tendons or neurovascular structures. Initial coverage after significant lower extremity trauma in these 100 patients required 59 split thickness skin graft, 6 local muscle flaps, 28 local fascio-cutaneous flaps, 5 free flaps and 2 cases were managed by simple closure. These reconstructive techniques had been selected according to wound location, its severity, and flap availability. The traditional role of the gastrocnemius muscles for flap coverage of knee and proximal leg defects and the soleus muscle for the middle third of the leg was reaffirmed. The cross leg flap and local fasciocutaneous flaps were most valuable for defects of the lower leg or foot, otherwise, a free flap would have been necessary.

INTRODUCTION

Treatment of high energy lower extremity trauma with soft tissue and bone injury remains a formidable problem. Treatment requires a team approach with the orthopedic, vascular and plastic surgeon. The goal in treatment of open tibial fractures and lower extremity salvage is to preserve a limb that will be more functional than an amputation. If the extremity cannot be salvaged, the goal is to maintain the maximum functional length [1]. There are many possible reconstructive options, which developed or modified for reconstruction of defects in the lower limb. These include; skin grafts, local flaps, distant flaps, and free flaps. However, each of these techniques has its own limitations [2]. The experience with the use of these reconstructive options is developing in various centers. However, still the indications, the selection of a particular technique for the different cases are not well established and are rather a matter of personal judgment. Limb reconstruction is a long complicated process. Patients must be aware of the expected functional outcome. Patient selection is an important variable in evaluating the final outcome. Although normal function is not always achieved, most patients are grateful for their salvaged limbs [3].

The aim of the present thesis is to study the different reconstructive options for management of lower limb defects and to suggest an algorithm for soft tissue coverage in different parts of the lower limb.

PATIENTS AND METHODS

This study was carried upon one hundred patients suffering from lower limb soft tissue injury who were admitted to Assuit University Hospital in the period from January 2005 to June 2006.

All the patients received 1st aid resuscitative measures to minimize bleeding restore airway and correct shock. Detailed history was taken with special emphasis on the mechanism of trauma; the time elapsed since injury, history of previous surgical procedures. Then all the patients were subjected to full general and local clinical examination to assess the site and size of the defect, the presence or absence of exposed bone, tendons or neurovascular structures, the degree of wound contamination, the condition of nearby skin (wounded, burned, infected or healthy) and full vascular and neurological examination with comparison to the other healthy limb when possible. Laboratory investigations necessary for surgical fitness were done. X-rays and Doppler studies were done when indicated.

Skeletal stability and restoration of the circulation of the injured limb was achieved.

The sites of the lesion were grouped into the following groups:

Thigh, knee, leg; which was further subdivided into upper, middle and lower third and multiple regions.

Lastly the foot; which was further subdivided into dorsum, sole, medial malleolus, lateral malleolus, and anterior aspect of ankle, tendo-Achilles and multiple regions.

The appropriate reconstructive technique was selected for every patient according to the reconstructive ladder putting into consideration the site, size and type of the defect (Simple or complex), the condition of local tissues, the vascular status of the affected limb, previous surgical procedures in the injured limb and patient's general condition especially the neurological state.

Patients were classified into two groups according to the time of reconstruction:

Group I: Those who had immediate reconstruction within the first 72 hours following trauma.

Group II: Those who had reconstruction later on (delayed reconstruction) due to either:

1- The patient was haemodynamically unstable due to the trauma.
2- Impaired neurological status of the patient due to the trauma.
3- Suspected vascular injury of the limb.
4- Delayed transfer of the patient to the hospital.
5- Failed primary reconstructive procedure.
6- Uncertainty of the viability of the soft tissue, and the need for a second look debridement.

All the patients received postoperative care including proper antibiotic therapy, potent analgesics in the post-operative period, elevation of the limb to prevent edema and good monitoring of the flap color, temperature and capillary refill. Dressing of the skin graft was done on the 4th postoperative day except in the surgically denuded raw area after flap elevation in which dressing was done at the end of the 7th postoperative day. Assisted ambulation was allowed for the patients whenever possible at the end of the 2nd postoperative day to prevent deep venous thrombosis. Dependable weight bearing was allowed at the end of the 7th postoperative day and this was according to the presence of bone fractures and the method of bone fixation. Some patients received antithrombotic agents as those who have been bed ridden for a long period because of bone fractures, obese patients and polytraumatized patients.

Evaluation parameters included viability and stability of the flap in cases managed by flaps, take of the skin graft in cases managed by skin grafts, presence of pain and ulceration and hospital staying.

RESULTS

The ages of the patients ranged between 3 and 66 years with a mean age of 19.76. Female to male ratio of 1:4.

The most common cause of injury was motor car accident (81%). This was followed by crush injury (6%), machine injury (4%), falling from height (2%), firearm injury (2%), gunshot injury (2%), cart accident (2%) and animal kick (1%).

The most common single site of injury was the foot (43%). This was followed by the leg (36%), the thigh (7%) and the knee (6%). More than one region of the limb was involved in 8% of cases.

As regards the foot, there were 43 injuries. The most common injured site in the foot was the dorsum (67.4% of foot injuries). This was followed by the sole (14%), the anterior aspect of the ankle (7%), the medial malleolus (4.7%), the lateral malleolus (4.7%) and the tendo Achilles (2.3%).

There were 36 injuries in the leg. Most of the lesions involved more than one third of the leg (44.4% of leg injuries). The single most common injured site in the leg was the middle third (27.8% of leg injuries). This was followed by the lower third (22.2%), then the upper third (5.6%).

54 cases were with simple wounds with no exposed bone, tendons or neurovascular structures (54% of cases). 46 cases were with complex wounds with exposed bone, tendons or neurovascular structures (46% of cases).

60 cases had immediate reconstruction within the first 72 hours (60% of cases). 40 cases had delayed reconstruction (40% of cases).

Hospital stay of the patients ranged from 3 days to 178 days with a mean of 25.13 days. The most important single factor which affected the time of hospital stay of the patients was the time of reconstruction; weather immediate or delayed.

- In Group I (cases that had immediate reconstruction): The mean hospital stay was 19.42 days.
- In Group II (cases that had delayed reconstruction): The mean hospital stay was 34 days.

Different reconstructive procedures were used according to the site of the defect and the presence of exposed bone, tendons or neurovascular structures (Table 1).

There were 7 cases presented with lesions in the thigh. All the lesions were simple; consisted only of skin loss with no bone or neurovascular structures exposed. All the lesions were managed successfully with split thickness skin graft. There were 6 cases presented with lesions in the knee region. 4 lesions were simple with no bone, tendons or neurovascular structures. These were managed by split thickness skin graft except one lesion on the popliteal fossa which was managed by a rotational flap. 2 lesions consisted of skin and soft tissue loss with exposed bone (patella) and these were managed by gastrocnemius muscle flap (one with medial head and one with both heads of the gastrocnemius).

There were 36 cases presented with lesions in the leg. The reconstructive procedures used and their results are shown in Table (2).

There were 43 cases presented with lesions in the foot. The reconstructive procedures used and their results are shown in Table (3).

Clinical Cases

Case (1-A): Preoperative post-traumatic defect at the upper 1/3 of the leg.

Case (1-B): Intraoperative medial head of gastr-cenmius muscle was transposed to cover the defect.

Case (1-C): Late postoperative show a very nice healed split thickness skin graft over the muscle.

Case (2-A): Preoperative open fracture of the tibia over the middle 1/3 of the leg.

Case (2-B): A posterior calf fasciocutaneous flap was transposed to cover the defect.

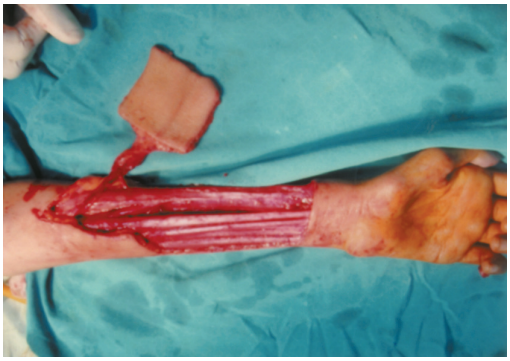
Case (2-C): Late postoperative with good quality and appearance of the flap.

Case (3-A): Preoperative post-traumatic defect on the lower 1/3 of the leg and ankle.

Case (3-B): A reversed sural artery flap was used to cover the defect.

Case (3-C): Late postoperative show excellent coverage and nice flap appearance.

Case (4-A): Preoperative post-traumatic defect on the medial side of the foot with exposed bone.



Case (4-B): Elevation of the free radial forearm flap.

Case (4-C): Late postoperative show good coverage of the defect.

Case (4-D): Minimal donor site morbidity.

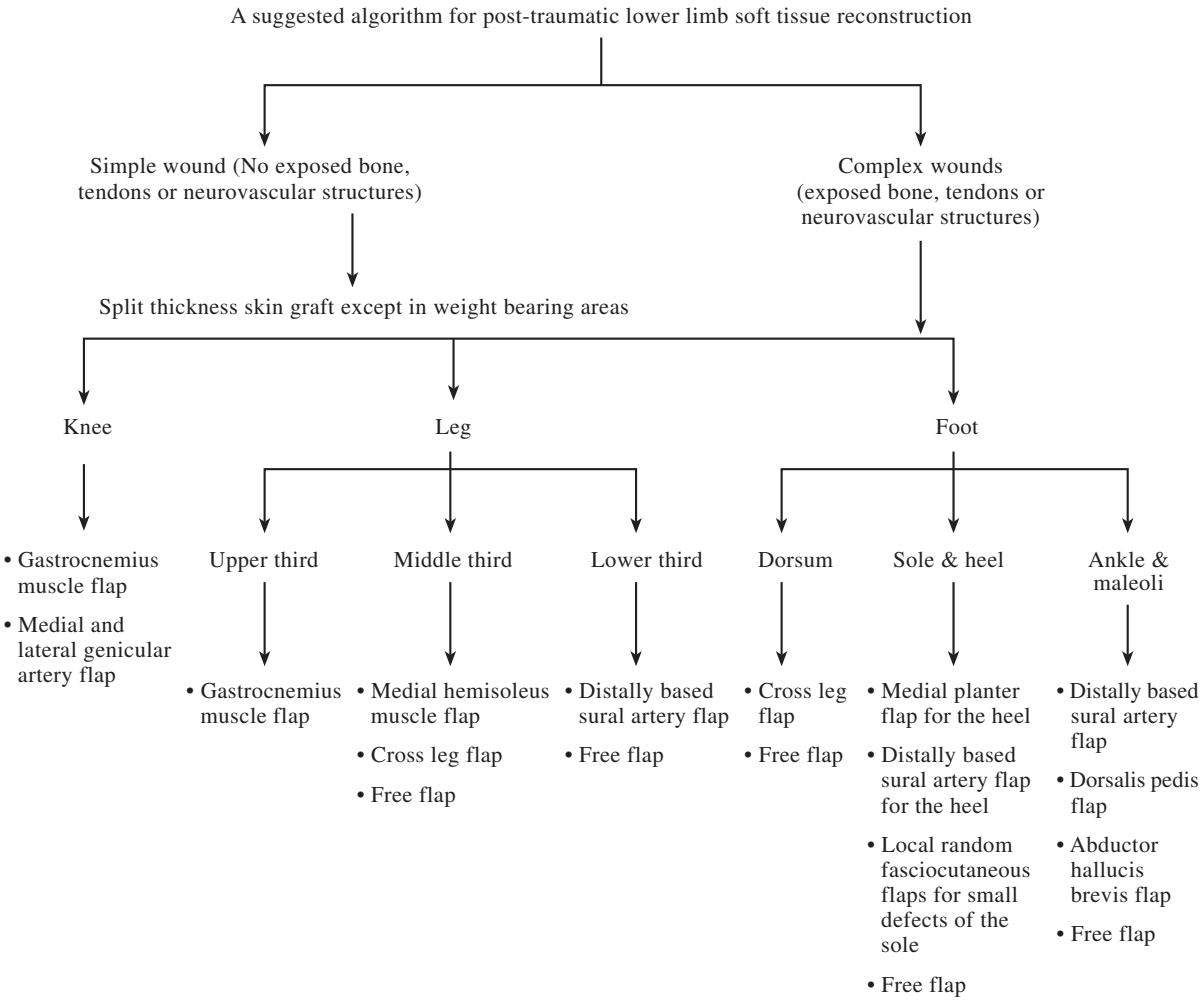


Fig. (1): Show a suggested algorithm for post-traumatic lower limb soft tissue reconstruction

Table (1): Different reconstructive procedures used in the lower limb.

	Split thickness skin graft	Simple closure	Cross leg flap	Distally based sural flap	Gastrocnemious flap	Hemisoleus muscle flap	Dorsalis pedis flap	Transposition flap	Bilateral VY flap	Abductor hallucis flap	Free radial flap	Free latissimus flap	Free parascapular flap	Total
Thigh	7	0	0	0	0	0	0	0	0	0	0	0	0	7
Knee	3	0	0	0	2	0	0	1	0	0	0	0	0	6
Leg	23	1	3	3	1	2	0	3	0	0	0	0	0	36
Foot	19	0	9	6	0	0	1	1	1	1	2	2	1	43
Multiple regions	7	1	0	0	0	0	0	0	0	0	0	0	0	8
Total	59	2	12	9	3	2	1	5	1	1	2	2	1	100

Table (2): Reconstructive procedures used in the leg and their results.

	Split thickness skin graft	Simple closure	Cross leg flap	Reversed small flap	Gastrocn-emious flap	Hemisoleus muscle flap	Transposition flap	Total
Leg:								
Upper third:								
Count	1	0	0	0	1	0	0	2
Result	Good take of the graft	–	–	–	The flap completely survived	–	–	
Middle third:								
Count	3	1	3	0	0	2	1	10
Result	One excellent take. Two good take	Complete healing	Complete survival	–	–	One completely survived, the other completely lost	Complete survival	
Lower third:								
Count	3	0	0	3	0	0	2	8
Result	Good take	–	–	Two of them completely survived the third was ischemic	–	–	One survived, the other had necrosis in distal 1/3	
Multiple regions:								
Count	16	0	0	0	0	0	0	16
Result	One excellent take. 8 good. 6 poor. one complete loss	–	–	–	–	–	–	
Total count	23	1	3	3	1	2	3	36

Table (3): Different reconstructive procedures used in the foot and their results.

	Split thickness skin graft	Cross leg flap	Reversed small flap	Dorsalis pedis flap	Trans-position flap	V-Y flap	Abducior hallucis brevis muscle flap	Free radial forearm flap	Free latissmus dorsi flap	Free paras-capular flap	
Foot:											
Dorsum:											
Count	15	9	1	0	0	0	0	2	1	1	29
Result	8 excellent take. 6 good take. 1 poor take	All completely survived only one had dehiscence	Completely survived	–	–	–	–	One completely survived the other was ischemic	Completely survived	Completely survived	
Sole:											
Count	1	0	3	0	0	1	0	0	1	0	6
Result	Good take	–	Complete survival	–	–	Complete survival	–	–	Ischemic	–	
Medial malleolus:											
Count	0	0	0	1	0	0	1	0	0	0	2
Result	–	–	–	Complete survival	–	–	Complete survival	–	–	–	
Lateral malleolus:											
Count	1	0	1	0	0	0	0	0	0	0	2
Result	Complete loss	–	Ischemia of distal 1/3	–	–	–	–	–	–	–	
Anterior aspect of ankle:											
Count	1	0	1	0	1	0		0	0	0	3
Result	Excellent take	–	Somplete survival	–	Complete survival	–	0 –	–	–	–	
Tendo achilles:											
Count	1	0	0	0	0	0	0	0	0	0	1
Result	Poor rake	–	–	–	–	–	–	–	–	–	
Total count	19	9	6	1	1	1	1	2	2	1	43

DISCUSSION

The overall results showed that immediate wound reconstruction, whenever possible, is preferred to delayed wound reconstruction in that it shortens the period of hospital stay significantly; in our thesis from a mean of 34 days in cases with delayed reconstruction to 19.42 days in cases with immediate reconstruction. This is associated with less pain with dressing changes, fewer operations, decreased infection rate and secondary necrosis of exposed tissues. Thus, early consultation for soft tissue reconstruction is advised and all attempts should be done to perform immediate reconstruction. These results are in agreement with previous studies **[3,4,5]**.

In our thesis, 54 cases were managed with split thickness skin graft. Split thickness skin graft was an excellent choice and was considered the first reconstructive option when only muscle or fascia was exposed. However, in the weight bearing areas in the foot, they mostly can not withstand pressure and are subjected to repeated ulcerations. Also, around the knee joint, complications in the form of contractures and repeated ulcerations are common. These results are in agreement with others **[6]**.

The gastrocnemius muscle flap was used in 3 patients. Two flaps were applied on the knee and one flap on the upper third of the tibia. In two cases the medial belly was used and in the third case both bellies of the muscle were used. The muscle was covered immediately with split thickness skin graft. The flap survived completely in all patients. These results show that the gastrocnemius muscle flap is indeed a highly reliable flap that could be used safely to cover defects over different aspects of the knee and the upper third of the leg. These results are in agreement with other studies **[7-11]**.

Two medial hemisoleus muscle flap with split thickness skin graft were used for coverage of exposed tibial fractures at the middle third of the leg in two cases in this study. One case was proximally based and the other was distally based. The proximally based flap completely survived with no complications but the distally based flap was completely ischemic. The proximally based flap is a reliable local option for soft-tissue coverage of a less extensive tibial wound in the middle third and the junction of the middle and distal thirds of the leg with good outcome and minimal morbidity. This is in agreement with **[12,13]**. The distally based hemisoleus muscle flap is unreliable because the dissection in the proximal soleus muscle is difficult, and the smaller inferior pedicles are less predictable in location and size. This is in agreement with Mathes & Nahai **[2]**. However, this is not in agreement with others **[13-16]**.

Abductor hallucis brevis muscle flap and split thickness skin graft was used in our study to cover a defect on the medial malleolus. The flap completely survived and the graft readily took over the muscle. Abductor hallucis brevis muscle flap offers versatile and well-vascularized tissue to cover defects at the medial aspect of the foot. This result is consistent with **[17]** who used this flap also to cover defects on the calcaneus and the forefoot.

In our study, five cases were managed by local random pattern fasciocutaneous flaps; either transposition or rotational flaps (one case in the popliteal fossa, 3 cases in the leg and one case in the anterior aspect of the ankle). All of these flaps were proximally based. Only one flap (20% of cases) had tip necrosis and was left to heal with secondary intention. These results show that local random pattern fasciocutaneous flaps are simple to raise, sensate, replace like with like tissue, ideal for smaller defects and require no unusual surgical skills. A disadvantage of fasciocutaneous flaps is the unsightly donor site, and therefore their use should be avoided in young females. They remain one of the useful methods of skin cover for lower extremity defects. These results are in agreement with other studies **[18-22]** who reported nearly similar complication rates, varying from 12 to 26%.

Chittoria & Mishra **[23]** Reported a much lower complication rate (one flap out of twenty had tip necrosis). However, these results are not in agreement with others **[24]** who reported a 38% incidence of tip necrosis in proximally based fasciocutaneous flaps.

Nine distally based sural artery flaps were used in the leg and foot from which six flaps completely survived, two had necrosis of the distal third and one flap was completely lost. These results showed that the distally based superficial sural artery flap could be considered the main line of treatment in similar defects in the lower leg, malleoli, ankle joint, weight bearing heel and even the dorsum of the foot. In addition to being one-stage operation, it is easy to perform with little expertise, quick to elevate, has a wide arc of rotation with reliable and constant vascular supply and there is no need to sacrifice any major artery or sensory nerve. These results in agreement with others **[25,26,27]** who have been able to use this flap to cover defects of the dorsum of the foot **[28-32]**.

Twelve cross leg fasciocutaneous flaps were applied and the survival rate was 100%. This flap was used successfully to cover large defects on the leg and dorsum of the foot. These results show that cross leg flap is a very reliable flap for leg and foot defects if properly designed and transferred in selective cases where other flaps are expected to be risky or not feasible. These results are in agreement with others **[33,34]**. However, these results are not in agreement with many other authors who report that cross leg fasciocutaneous flaps should not be considered frequently in current medical practice due to the availability of other ipsilateral flaps like fasciocutaneous flaps, muscle and musculocutaneous flaps and free flaps **[35]**.

In our thesis, one dorsalis pedis flap was used to reconstruct a defect on the lateral malleolus and it completely survived. Delayed donor site healing and donor site morbidity was the major drawback of this flap; however these were accepted as compared with the benefits achieved. These results are in agreement with others **[36,37,38]**. However, Samson, et al. **[39]** reported that this flap should be used with caution as all patients had initially experienced delayed donor-site healing.

The free latissimus dorsi flap was used for two cases in the present study. Unfortunately, one flap survived and the other one was ischemic.

Free fasciocutaneous flaps were used in three cases; two radial forearm and one parascapular flaps. Two of the three flaps completely survived and the third one was completely ischemic. The failure in both cases could be attributed to the condition of the recipient vessels (being in the proximity to the zone of injury).

The results of this thesis show that free tissue transfer has several advantages. It offers a well vascularized tissue to close cavities or defects of diminished vascularity. It can be carefully picked from an area that has not been traumatized too match the existing functional and aesthetic lower leg or foot defects. The donor morbidity can be kept to a minimum. They can be of large size. However, they are lengthy procedure; require the availability of well trained micro-vascular team and sophisticated equipment and high cost. A high degree of success can be achieved only by extremely careful patient selection. This is consistent with **[40,41,42]**.

Conclusion:

As regards defects in regions of the lower limb at the thigh, skin grafting should be considered as the first line of closure, followed by rotational flaps. This is because the muscle flap of the thigh acts as an envelope that serves as a source of protection for the underlying bone and neurovascular structures. It also provides a well vascularized bed for split thickness skin graft application.

For complex defects around the knee region and upper third of the leg, the gastrocnemius muscle flap is a reliable flap with a good range of movements allowing it to reach most aspects of the knee.

Regarding defects of the middle third of the leg, the proximally based hemisoleus muscle flap is the flap of choice, however, cross leg fasciocutaqneous flap is another excellent choice in spite of its drawbacks like inconvenience, discomfort and hospitalization for four weeks which were relatively insignificant as compared with the benefits achieved. It should be avoided in cases with diabetes, hypertension, previous history of thrombosis and stiffness in either leg.

For the distal third of the leg, the distally based sural island flap is an excellent choice. Local random fasciocutaneous flaps should also be considered. Larger defects in the distal third are an indication for free flap transfer.

In cases of foot defects, each site has to be considered separately. Thus on the dorsum of the foot, cross leg flap is the simplest solution. Otherwise, one has to use a free flap, especially those of thin skin as parascapular flap. However, distally based sural artery flap can be used to cover defects on the dorsum of the foot.

Heel defects are best managed with medial planter flap, however distally based sural artery flap is another option. For smaller defects in the sole, one can use simple reconstructive options: Rotation, transposition or V-Y advancement flap. For larger defects, free flaps are optimal, provided that they are well tailored.

For the ankle joint or malleolar defects, local flaps are ideal. The abductor hallucis brevis muscle flap can be used to cover the exposed medial malleolus. Dorsalis pedis flap, distally based sural artery flap and local random pattern flaps can be used to cover such defects of the ankle or the malleoli.

We emphasize the importance of co-operation at the time of primary surgery between orthopedic and plastic surgeon to preserve access to potential flaps. The technique of bony fixation of the tibia may prevent the use of this flap, especially in the

presence of external fixation pins which may injure perforating vessels or tether the flap, restricting its range of transposition.

Finally, the following algorithm may be proposed as a protocol for the management of lower limb defects.

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