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REVIEW ARTICLE

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Fasciocutaneous Flaps of the Lower Leg: Relationship of Pedicle Length, Working area of Flap and Flap Survival

R. Ekpo[1], I. I. Onah[2], REE Nnabuko[3]O. Otei[4], M. Ozinko[5], E. Isiwele[6] and M. Asuquo[7]

[1,4,5,6]Division of Burns, Plastic and Reconstructive Surgery, Surgery Department, University of Calabar, Nigeria

[2, 3]Burns, Plastic & Reconstructive Division, National Orthopadic Hospital, Enugu

[7]Division of Proctology/General Surgery, Surgery Department, University of Calabar

ABSTRACT

The fasciocutaneous flap is a versatile local flap option for the reconstruction of distal one third of the leg. The aim of the study was to determine the relationship between flap pedicle length and working area of flap raised without the aid of Doppler Ultrasound Scan (DUSS) and percentage flap survival. A six month prospective study was carried out at National Orthopedic Hospital, Enugu, Seventeen patients were consecutively recruited into the study. All patients met the inclusion criteria. All patients were adults. The age range was 18 years to 61 years (39.0 ± 3.4 years) and the female to male ratio was 1:2. Higher proportion of patients [n=12), 70.6%] demonstrated good flap survival for varied length of flappedicles and working area of flaps raised without the aid of DUSS. The mean duration of hospital stay was 62.2 = 7.0 days. The use of local fasciocutaneous flap raised without the aid of DUSS for closure of post-defect of distal one third of the leg should be encouraged especially in District hospitals or referral centers with dearth of medical facilities.

Keywords: Fasciocutaneous flap, wound cover and lower leg trauma.

INTRODUCTION

The distal on third of the leg has inherent problematic features namely paucity of soft tissues and poor vascular supply to the region. Post traumatic defect of the lower third of the leg presenting as open wounds, open tibial wounds, compound fractures and avulsion injuries of the lower third of the leg are a common presentation in the Accident and Emergency unit of National Orthopedic hospital, Enugu, Nigeria. These post traumatic defect may result from high energy lower extremity trauma, pedestrian motor vehicle accident, falls from heights, sporting injuries, gunshot injuries, bomb blast injuries, electric injuries and even post-surgical procedure.

The Management of these post traumatic defects of the distal one third of the leg often associated with soft tissue loss and or compound fracture of the tibia bone remains a challenge for the reconstruction surgeon (Bhatt, 2007 and Ebrahimi, 2011).

The available autogenous supple soft tissue cover options for reconstruction of this post traumatic defect of the distal one third of the leg are local pedicle flaps and free microsurgical flaps. The employment of local, regional pedicle flaps may involve use of fasciocutaneous flap, adipo fascial flap and muscle flap. In our sub region, where there is dearth of expertise and facilities for microsurgical free tissue transfer, a readily available cost effective, simple alternative for the reconstruction of distal one third of the leg is local fasciocutaneous flap cover. Local fasciocutaneous flap surgeries are known to be associated with fewer surgical complications namely bleeding, deep vein thrombosis, and wound sepsis. The advantages include shorter operation time and hospital stay, better anesthetic outcome with low donor site mobility and a low incidence of osteomyelitis and nonunion when employed promptly. The use of fasciocutaneous flaps for reconstruction of post traumatic defect of the lower leg will continue to evolve.

Historically, the viability of cutaneous flap without the deep fascia in the lower leg was based on a length to width ratio 1:1 Bengt Ponten of Sweden in 1981 demonstrated that if the deep fascia was included and oriented along its longitudinal axis, an extra ordinary viability with a 3:1 length to width ratio can be obtained [14]. Robotti et al[15] in a study at the battle front during the Bosnia – Herzegovina conflict demonstrated reliability of the distally based fasciocutaneous flaps even with length to width ratio of 5:1.Most interestingly, the study was done with no pre-operative arteriography or Doppler ultrasonography (DUSS) and the injuries occurred in a warridden zone with no feasible means of evacuating the victims to centers with “State of the art” facilities.

To overcome our unique problems in the management of post traumatic defects of distal third of the leg, the authors decided to embark on this study to determine the relationship of pedicle length, working area of flaps and flap survival.

PATIENTS AND METHODS

The prospective study was carried out in 2012 at National Orthopedic Hospital, Enugu, Nigeria. A total of seventeen patients were recruited into the study within six months interval. Patient who met the inclusion criteria were recruited consecutively from the accident and emergency unit and the out-patient department of the hospital. The inclusion criteria were soft tissue wounds of distal third of the leg, compound fractures with Gustilo grade IIIa and IIIb, open tibiafractures, avulsion injuries with or without exposed tendons, nerves and blood vessels and exposed implant materials from previous operation on the distal one third of the leg.

The exclusion criteria included patients sustaining Gustilo and Anderson type I, II, and IIIc open tibia fractures, arterial disease, and/or venousulcers, high tension electric burn wounds, mangled and crushed extremely wound, patients with uncontrolled systemic disease example diabetesmellitis, congestive cardiac failure and severe jaundice, geriatric patients with co-morbidities and patient less than 18 years of age.

All the patients followed a treatment protocol designed for the study. Patient who presented through the accident and emergency unit of the hospital were treated as surgical emergencies. Demographic information and clinical history of each was obtained, physical examination noting defect size, structures affected and vascular supply, and relevant investigations were done as indicated. Plain x-ray films were taken of the affected bone(s) after temporary splint application.

Antitetanous, analgesics and antibiotics were administered. In the accident and emergency (A & E) theatre thorough wound debridement and copious irrigation with normal saline was done. Stabilization of fractured bone(s) if any with the use of external fixators was carried out by the orthopedic surgeon while in the theater.

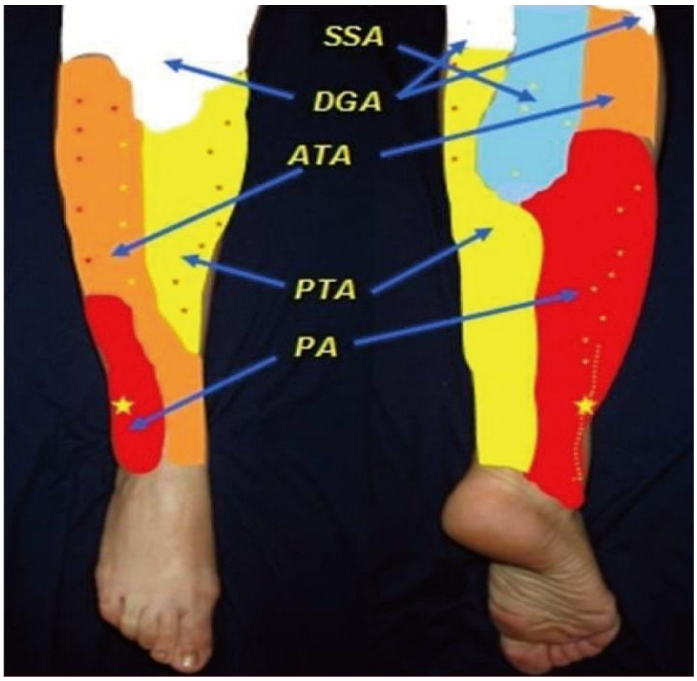
Patients were then rescheduled for a second look procedure after 48 hours. Definitive flap procedure was planned during the look procedure. The patient(s) were adequately informed about the study. Their cooperation and consent for the study and publication solicited. The definitive treatment modality whether superiorly based, inferiorly based, bi-pedicle or reverse sural fasciocutaneous flaps cover and post-operative evaluation as stated in the objective of study were documented.

Blood supply to fasciocutaneous flap

A review of the works of Manchot 1889, Salmon 1936 and Taylor and Palmer 1983 on vascular territories of the distal one third of the leg showed that the cutaneous arteries arise either directly from the underlyingsource arteries or indirectly from branches of these source arteries to the deep fascia.

These arteries destined to perforate the deep fascia to the skin follow the connective tissue frame work and course from the deep tissue and for variable distance beneath the deep fascia. They then pierce the deep fascia at specific skin sites as cutaneous perforators.

The source arteries give off the cutaneous perforators for the distal one third of the leg including posterior tibia, anterior tibia and peroneal arteriess (Diagram A).



Themain distributions of perforators in each cutaneous territory
(Courtesy of: Georgescu AV. Propellar Perforator Flaps in Distal Lower Leg: Evolution and Clinical Applications. Arch Plast Surg 2012; 39: 94-105)
The small stars represent the main distribution of perforators in each territory.
SSA: Superficial Sural Artery
DGA: Descending genicular artery
ATA: Anterior Tibial Artery
PTA: Posterior Tibial Artery
PA: Peroneal Artery

These branches of vessels interconnect forming a three dimensional vascular territory called an angiosome. Adjacent angiosomes are connected via similar caliber (true) vessels or reduced caliber (choke) vessels. The interconnectivity is both horizontally and vertically.
Fasciocutaneous flaps contain the skin, subcutaneous tissue and the deep fascia. The vascularization of a fasciocutaneous flap is both axial and random pattern supplemented by fasciocutaneous perforators. The axiality in the subcutaneous tissue was demonstrated by some Japanese authors.

SURGICAL TECHNIQUES
The procedure and choice of flap design varied depending on the nature of injury and how supple was the surrounding skin. The choice of anaesthesia was either spinal anaesthesia or general anaesthesiawith cuffed endotracheal intubation. The position of the patient was dictated by the choice of flap design, and a pneumatic tourniquet applied at the proximal thigh of the affected limb. Skin prep for both lower limbs including contralateral thigh if grafting of secondary defect is indicated. Patient was draped with exposure of operation site(s).

Reversal Sural Artery Fasciocutaneous Flaps
The marking was commenced by drawing a line from a point midway between the lateral malleolus and the Achilles tendon. This line was then extended proximally to the midline at the junction between the proximal third and distaltwo -third of the leg which correspond to the two heads of gastrocnemius muscle. This line roughly follows the course of the sural nerve. The peroneal perforators were marked at 5 – 13 cm proximal to the tip of the lateral malleolus. A template of the defect was made and used to design a skin island on the posterior calf. The pivotal point of the pedicle was made at 5 cm or three fingers' breadth above the lateral malleolus to allow for the last perforator from the peroneal artery.
The pneumatic tourniquet was then inflated 100 – 200 mm Hg above the patients' pre-operative systolic blood pressure.
The skin incision started along the line marked for the fascial pedicle. The subcutaneous layer was then dissected exposing the sural nerves, accompanying superficial sural vessels, and the lesser saphenous vein. An hypodermal fascial pedicle was elevated with a width of about 2 – 4cm thereby increasing the probability of capturing of the neurovascular bundle.
The incision was deepened through the fascia. A finger was then introduced through the opening on the fascia and using the finger the fascia was lifted up from the muscular layer underneath using blunt dissection. A careful subfascal blunt dissection was carried out until the flap was loose and freely mobile. The skin island was raised with the deep fascia. The

flap was carefully mobilized and in set into the defect by either tunneling or division of the skin bridge and exteriorizing the pedicel to avoid pressure on it.
The recipient wound bed was prepared by thorough wound debridement including excision of wound edge and generous irrigation with copious amount of normal saline. The flap was anchored to the defect's bed using fine non absorbable sutures. The donor defect was then grafted with split thickness skin graft harvested from the contralateral high or ipsilateral thigh if the contra-lateral thigh was unsuitable. The donor site was dressed with Opsite and the recipient site with non-adherent (sutra tulle) gauze, capillary gauze layer and absorbent gamgee. A loose crepe bandage was then applied to support the under dressing. A full length of back slab Plaster of Paris [POP] cast was applied for five days to ensure immobilization of the limb.
The pneumatic tourniquet was deflated after the allowed time of 90 minutes and not exceeding 120 minutes irrespective of the stage during surgical procedure.

Superiorly based or inferiorly based Fasciocutaneous Flaps
The patient's position on the table and the decision on whether to base the flap pedicle superiorly or inferiorly were pre-operatively determined. The choice of anaesthesia was either spinal anaesthetic block or general anaesthesia. Following anaesthesia, the patient was positioned depending on the geometric configuration of the wound. Patient's position was changed as necessary. A pneumatic tourniquet was applied on the proximal thigh of the involved limb for each patient and timed.
Skin preparation and draping with exposure of operation site (s) was carried out accordingly. Depending on the defects size and geometric configuration of the defect, the flap was based either superiorly or inferiorly. The fasciocutaneous flap was marked out longitudinally along the long axis of the leg with the pedicle based either superiorly or inferiorly and also taking into consideration the anatomical locations of the perforator vessels.
That incision was made through the skin, subcutaneous layer and the fascia. A skin hook was used to lift up the fascia, avoiding hooking on the skin when handling the flap. The incision was started in an area where the fascia was easily identified. A finger was the passed through the opening on the fascia, which was then lifted up from the muscles underneath by bluntdissection. A careful subfascial blunt dissection was carried out until the flap was loose and freely mobile. In some instance, the flap was lengthened to facilitate transportation by making a back cut and this gave an extra centimeter that was necessary to absolutely relax the flap over the defect. The flap was then transposed into the defect. The pneumatic tourniquet was deflated and hemostasis secured. Fine non-absorbable suture example nylon 2/0 suture was used to appose the skin edges. Care was taken to avoid tension on the flap.
The secondary defect was covered with a split thickness skin graft. The donor site was dressed with Opsite, while the recipient site was dressed with soft padding made up of non-adherent gauzes (sufra-tille), capillary gauze layer, absorbent cotton wool or gamgee and then secured with crepe bandage.

POST OPERATIVE CARE
The authors avoided the use of tight wound dressing. An opening that was created on the dressing allowed for the monitoring of the flaps in some cases. Monitoring of the flap was carried out by the examining for skin colour, capillary refill, pricking of the flap and temperature recording of the flap by use of infra-red thermometer.

The limbs operated upon were elevated on two or three pillows; to keep their wound dressing dry and avoid putting pressure on the flap sites(s). All the patients were given analgesics and intravenous antibiotics. The patients were reviewed on a regular basis.
First exposure of the operation site for the purpose of assessment was done on the third and/or fifth day{s} respectively. Thereafter wound site inspection and dressing was continued on alternate days.
The sutures were removed after ten to fourteen days.
The patient(s) were discharged home following healing and follow up was scheduled at the outpatient department at two weekly intervals.

The effectiveness of each flap type was evaluated based on;

a. The viability and survival of the flap
b. Satisfactory wound cover of exposed bone(s), tendons or neurovascular structures.

Postoperative flap survival was assessed clinically and flap was documented in ordinal form to facilitate statistical analysis.

The clinical documentation was based on the following considerations:

i. Marginal flap necrosis consisted of a flap necrosis occurring at the flap margin but less than 25% of the flap surface area.
ii. Partial flap loss consisted of loss of flap viability not exceeding 50% of the flap surface area.
iii. Total flap loss was considered when the post-operative loss of flap was in excess of 75% of the flap surface area.

The flap survival outcome was documented in the ordinal form for statistical analysis as follows:

Complete survival	-	4
Marginal flap loss	-	3
Partial flap loss	-	2
Total flap loss	-	1

The final outcome of flap surgery was graded as good or poor.

a. Good flap outcome implied flap survival or loss in the range of ≥ 3 in ordinal form.
b. Poor flap outcome implied flap loss in the range of ≤ 2 in ordinal form

RESULT

Data analysis was done using SPSS version 19.0 for windows and computer programme for epidemiologic analysis (CPEA)
Seventeen (17) patients were recruited for the study. The age range of the patients was 18 to 61 years, with a mean of [39.0+3.1] years. There was preponderance of males with a female to male ratio 2:1.Eleven patients [64.6%] out of the Seventeen patients sustained post traumatic defect to the distal one third of the leg following road traffic accident (RTA). Other causes of post traumatic defects to the lower third of the leg were gunshot injuring

[11.8%], implant exposure from previous surgery [11.8%], industrial accident [5.9%] and fall – domestic accident [5.9%].

Table 1. Clinical Data on Prospective Study Group.

S.No.	Diagnosis	Wound Size (cm)	Size of wound area (CM^2)	Length of flap pedicle (cm)	working area of flap (CM^2)	Flap Design
1	Open tibial wound 2^0 fall	4x7	28	11	55	Superiorly based Fasciocutaneous Flap
2	Gustilo Type IIIB open tibial fracture 2^0 GSI	5x6	30	9	54	Reverse Sural Flap
3	Gustilo Type IIIB open tibial fracture 2^0 RTA	3x4	12	7.5	30	Superiorly based Fasciocutaneous Flap
4	Gustilo Type IIIB open tibial fracture 2^0 RTA	4x6	24	9	45	Reverse Sural Flap
5	Gustilo Type IIIB open tibial fracture 2^0 RTA	6x8.5	51	12	84	Superiorly based Fasciocutaneous Flap
6	Implant Exposure from previous surgery	2x5.5	11	10	30	Bipedicle Fasciocutaneous Flap
7	Avulsion Injury with Achiles tendon rupture 2^0 RTA	5x5	25	9	54	Reverse Sural Flap
8	Gustilo Type IIIB open tibial fracture 2^0 GSI	4x6	24	11	55	Superiorly based Fasciocutaneous Flap
9	Gustilo Type IIIB open	3x7	35	9.5	57	Inferiorly based Fasciocutaneous

	tibial fracture 2^0 RTA					Flap
10	Avulsion Injury with Achiles tendon rupture	4x5	20	8	40	Reverse Sural Flap
11	Gustilo Type IIIB open tibial fracture 2^0 RTA	6x8	48	12	84	Delayed Inferiorly based Fasciocutaneous Flap
12	Gustilo Type IIIB open tibial fracture 2^0 RTA	4x5	20	10	50	Reverse Sural Flap
13	Avulsion Injury with Achiles tendon rupture 2^0 RTA	4x4	16	8	40	Reverse Sural Flap
14	Gustilo Type IIIB open tibial fracture 2^0 RTA	3x6	18	7.5	30	Reverse Sural Flap
15	Implant Exposure from previous surgery	3x5	15	9	36	BipedicleFasciocutaneous Flap
16	Gustilo Type IIIB open tibial fracture 2^0 RTA	5x7	35	11	66	Inferiorly based Fasciocutaneous Flap
17	Open tibial injury 2^0 RTA	6x8	48	12	84	Reverse Sural Flap

Twelve patients [70.6%] sustained post traumatic defect to the distal one third of the left leg while five patients [29.4%] sustained post traumatic defects to distal one third of the right leg. The dimensions of the smallest wound size among the patients was 5.5cm×2cm while the largest wound size measured 8cm×6cm, the maximum wound area was $48cm^2$ as shown in table 1. The maximum working area of the flap which is equivalent to length of flap

pedicle times the width of the flap pedicle raised without the aid of DUSS to cover post traumatic defect of the distal one third of the leg was 84cm^2 [table 1].

Various local fasciocutaneious flap design was used in the study. The pre and post-operative clinical photographs for the two most commonly used flap designs are shown [-figure1 and figure 2] below.

Table 2. The relationship between Flap pedicle length, working area of flap and flap survival in the test (Prospective) group.

Variable	Flap Survival		P-value
Length of Flap pedicle (cm)	Good	Poor	
	N %	N %	
≤ 10	872.7	327.3	P = 1.000
> 10	466.7	233.3	
	1270.6	**529.4**	
Working are of flap (cm^2)			
≤ 54	770.0	330.0	P = 1.000
> 54	571.4	228.6	
	1270.6	**529.4**	

The post-operative complications were noted. The relationship between length of flap pedicle with flap survival and working area of flap with flap survival is summarized in table 2. The post-operative outcome showed good flap survival in the majority of the patients [n=12(70.6%)] as compared to those patients [n=5 (29.4%)] who had poor flap survival.

DISCUSSION

The management of Gustilo - Anderson type III and other post traumatic defects of the lower leg remains a challenge to the Reconstructive Surgeons. Soft tissue defects of the distal third of the leg are considered the most difficult to reconstruct due to paucity of subcutaneous tissue in the region, inherent subcutaneous location of the tibia bone in its anterior and anteromedial surfaces and worse still, the poor vascularity of the region. These features contribute to make suturing without tension in the region difficult and predisposes wounds to healing problems. Patients with post traumatic defects to the distal one third of the leg should be evaluated holistically and management should commence early to prevent infection and other complications. One of the most important factors in the choice of definitive surgery is to provide a physiologic milieu for exposed tissues. This demands an urgent debridement of the wound, dressing with sterile moist gauzes soaked with normal saline or Ringers lactate solution providing a physiologic milieu which bathe the damaged tissues and bandage over it. The choice of definitive surgical procedure is then dictated by the state of the wound during the next visit in the theatre.

The preponderance of males in the study is possibly due to the inherent nature of males being more active by nature and more willing to take risks. Their incapacitation impacted negatively on their families and the nation. The families were starved of their income generation and even spend much more resources on their treatment while the nation suffered loss of great man-hours.

The major cause of post traumatic defects to the distal third of the leg was road traffic accident which was similar to findings in some other studies.

The most commonly used design of fasciocutaneous flap was reverse sural artery fasciocutaneous flap. The authors noted that the largest wound surface area covered was 6×8cm, which was smaller when compared to wounds measuring 8×15cm and 8×14cm by Onumaegbu et al and Touam et al respectively. The maximum length to width ratio of flaps used in the study was 1.7:1. A ratio almost comparable to 1.8:1 by Hallock[7] but far less when compared to 5:1 length to width ratio by Robotti et al. Surprisingly,all the authors recorded impressive flap survival with good healing outcome. Taking into consideration all the flap designs, a higher proportion of the patients [n=8(72.7%)] with length of flap pedicle ≤ 10cm showed good flap survival compared to those who suffered poor flap survival [n=3 (33.3%)] for patients with length of flap pedicle >10cm. A good percentage [n=4(66.7%)] showed good flap survival when compared with those [n=2(33.3%)] who developed poor flap survival. The emphasizes here is that patients with flap pedicle length ≤ 10cm raised without the aid of a Doppler ultrasound scan showed better flap survival than patients with length of flap pedicle >10cm raised without the aid of a DUSS. Overall, majority of the patients [n=12(70.6%)] showed good flap survival when compared to the few [n=5(29.4%)] who demonstrated poor flap survival. Though the p-value {p=1.000} was statistically insignificant, clinically this study has demonstrated that good flap survival can be achieved by using local faciocutaneous flaps raised without the aid of a DUSS for small to moderate length of flap pedicles.

Also the relationship between the working area of flap and flap survival was evaluated. It was observed that as the size of the working area of flap increased from 54cm^2 to 84cm^2 significant complication rate and poor flap outcome occurred. This observation was noted across the different types of flap designs. Seven patients out of ten patients with a working area of flap≤ 54cm^2 demonstrated good flap survival with no complication at all. Three other patients in the group developed minor complications ranging from wound dehiscence to wound infection. For patients with working area of flap >54cm^2, five out of seven demonstrated good flap survival with minor complications such as wound dehiscence and marginal flap necrosis while the remaining two patients demonstrated poor flap survival. Overall, patients with working area of flap ≤ 54cm^2 raised without the aid of DUSS demonstrated better flap survival than those with working area of flap > 54cm^2 raised also without DUSS. The fisher's exact test was statistically insignificant. The clinical implication is that good and satisfactory flap cover can be achieved with local fasciocutaneous flaps of small to moderate sizes of the working area for flaps raised without the aid of DUSS for coverage of post traumatic defects of distal one third of the leg.

The 54cm^2 mark serve as the cuff off for working area of flaps raised without the aid of DUSS, for coverage of post traumatic defects of the distal one third of the leg. This cut off mark was determined statistically and is slightly higher than figures in other studies.

CONCLUSION

Local fasciocutaneous flaps remain a cheap, reliable and versatile tool for the reconstruction of defects in the distal one third of the leg. In resource constraint settings as in most tropical countries without the luxury of medical infrastructures, employment of local fasciocutaneous flaps raised without the aid of DUSS should readily come to mind. These local fasciocutaneous flaps raised without DUSS also provide reliable coverage for small to medium sized defects for lower limbs particularly lower third of the leg. These flaps provide supple wound cover that is aesthetically acceptable.

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There were no conflicts of interest

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Corresponding author: Dr. Rijami Godwin Ekpo, Lecturer/Consultant Plastic Surgeon, Division of Burns, Plastic and Reconstruction Surgery, Surgery Department, University of Calabar, Calabar.
Email: rijigodwin@yahoo.com