Perforator-Plus Fasciocutaneous Flaps in the Reconstruction of Post-Burn Flexion Contractures of the Knee Joint

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ABSTRACT

BACKGROUND
Post-burn flexion contracture of the knee joint is a disabling condition which interferes with upright posture and bipedal locomotion. Islanded perforator flaps have been used to resurface the tissue defect produced as a result of contracture release. Despite their various advantages, they are limited by an increased tendency to undergo venous congestion. Perforator-plus flaps can be used to overcome this limitation while retaining the merits of islanded perforator flaps.

METHODS
Nineteen patients with post flame burn flexion contracture of the knee joint underwent surgical release and coverage by various local fasciocutaneous perforator-plus flaps. Patients were followed up for 6 months and the various aspects of functional and aesthetic rehabilitation were assessed.

RESULTS
All local fasciocutaneous perforator-plus flaps resurfaced the tissue defect over popliteal fossa with good color and texture match and maintenance of contour. None of the flaps had any significant early or delayed complications (including venous congestion) to necessitate reoperation. All patients were satisfied with the functional and aesthetic outcome.

CONCLUSION
Local fasciocutaneous perforator-plus flaps can be considered as one of the primary treatment modalities for surgical release and reconstruction of post burn flexion contracture of the knee.

KEYWORDS
Perforator-plus flap; Fasciocutaneous flap; Peninsular flap; Post-burn contracture; Knee joint

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INTRODUCTION

With a steady decline in the mortality of burn patients over the past six to seven decades, addressing the issues of disabling post burn squeal have become more vital in order to adequately rehabilitate the victim in society.[1] A burn patient who receives the best of treatment including early physiotherapy, adequate splintage in position of function and early debridement with skin grafting is expected to heal without any significant contractures. However, post burn contractures are distressingly common in India and other developing nations. The incidence of burn cases has been estimated to range from 60-70 lakhs annually in India.[2] In the emergency setting most cases are treated in ill-equipped peripheral units with inadequately trained staff. This, in turn, gives rise to the enormous burden of post-burn contractures and deformities which have to be dealt with in the comparatively few tertiary care centres.[2]

Post burn scar contractures over major joints of the body are characterized by presence of single-celled highly fragile neoepithelium which may be associated with long-standing shortening of underlying musculotendinous units and neurovascular structures as well as tightened joint capsules and ligaments. The knee is the largest joint of the human body and is involved in maintaining upright posture and bipedal locomotion. Adequate incisional or excisional release of flexion contracture of this joint leaves large skin defects and often exposes bowstringed hamstring tendons, major vessels and nerves in the popliteal fossa requiring soft tissue coverage. Those cases resurfaced with skin graft need prolonged splintage and rigorous physiotherapy for a minimum period of 6 months.[3,4] This leads to poor patient compliance. Therefore the rate of recontracture is more which needs re-operation and increases patient morbidity and burden on already stressed infrastructure. These shortcomings can be overcome by the use of flaps. However, the lower limb has been known to be a site of less reliable vascularity, poor wound healing and scarcity of flaps. Before the advent of free flaps few reconstructive options were present like conventional local flaps and cross-leg flaps which required immobilization for weeks.[5] Several muscle or musculocutaneous flaps have been used to repair soft tissue defects around the knee.[6-8] However, they are bulky, cause varying degrees of functional loss to an already crippled extremity and causes poor aesthesis of donor site. Random cutaneous and conventional fasciocutaneous flaps are simple, reliable, provide durable pliable coverage with better donor site esthesis and less morbidity. However, they are restricted by limited length: breadth ratio, need delays and have limited mobility and reach. The delicate balance between flap vascularity and reach in the lower limb was somewhat achieved with the advent of islanded perforator flaps.[9,10] It was recognized that skin overlying muscles can be reliably transferred separately from the muscle as an islanded flap based only on the dissected musculocutaneous perforators.[9,10] The donor site has minimal functional compromise and better esthesis. They provide thin, pliable coverage with tissue of similar color and texture, immense freedom of movement and maintain functional integrity of muscles and nerves while safeguarding the main vascular trunks. But an important pitfall of such flaps was venous compromise. This is because thin walled vein with lower vessel wall elasticity and intraluminal pressure is more sensitive to torsional forces than the perforator artery during flap transfer and inset.[11,12] The concept of perforator- plus flaps aims to combat this pitfall. This new method involves raising peninsular fasciocutaneous flaps including and retaining one or more perforators in their base.[13,14] This provides a dual blood supply through the perforator and subdermal plexus as well as reinforces the venous drainage. The pedicle may be narrowed by back cuts to facilitate mobility and tension free inset.[14] It has been determined that perforator-plus fasciocutaneous flaps can be safely performed in the knee, upper and middle thirds of the leg.[15,16] Moreover most cases of post burn contracture of the knee have limited locoregional unscarred tissue which increases the chance of flap failure. This is combatted by including a perforator in the flap base.[17,18] The aim of this paper is to evaluate the applicability of perforator-plus flaps in the reconstruction of post burn flexion contractures of the knee joint.

MATERIALS AND METHODS

Between August 2010 and March 2012, 19 patients with post-flame burn flexion contracture of the knee joint were operated in the

department of plastic and reconstructive surgery of our institution. A clearance was obtained from the institutional ethical committee and written informed consent taken from all the patients. All patients were managed by complete incisional or excisional release of contracture followed by coverage with local perforator-plus flaps. The patients were advised to quit smoking at least 2 weeks prior to surgery. The degree of contracture was assessed with a goniometer and the extent of defect to be produced was approximately estimated by comparing with the normal side (or limb of another subject of similar stature and build in case of bilateral involvement). The type of fasciocutaneous flap to be raised was then planned considering the location of defect and quality of surrounding tissue. Any perforator supplying the proposed flap territory was marked with the help of hand-held Doppler with 8 Hz probe. It was considered preferable but not mandatory to identify the perforator pre-operatively. The approximate dimensions of the flap were determined by planning in reverse. The length of the flap from the identified perforator (which marks the location of the base) is equal to the distance of the distal-most margin of the defect from that perforator plus one centimeter, to allow tension-free inset. After the induction of anesthesia the contracture was released completely, without damage to underlying vital structures, under tourniquet control. The final planning in reverse was done with a piece of lint and the modified outline marked out. The flap was then raised by a combination of sharp and blunt dissection preserving the supra and subfascial plexus. The perforator(s) at the flap base with strong intra-operative Doppler signal and visible pulsation was/were preserved. They were dissected retaining a cuff of areolar tissue around in order to ensure flap mobility and reach. The skin pedicle was narrowed with back cuts if needed to facilitate reach and inset without significant dog-ears. The flap inset was then accomplished without any tension on the pedicle. Placement of suction drain under the flap was considered optional. The donor site was covered by split-thickness skin graft .The flap was covered by light dressing and limb kept elevated post-operatively. Prophylactic antibiotics were given for 5 days. No special post -operative drugs or monitoring technique were needed. The dressing over the graft was removed on 5th post-operative day and sutures removed on the 10th day. No post-operative splinting was applied. Limb mobilization was begun after 1 week and gradual weight-bearing started two weeks post-operatively. The patient was followed up two weekly in the first month after discharge and monthly thereafter for 6 months.

RESULTS

A total of 19 patients of post-flame burn flexion contracture of the knee joint were operated between August 2010 and March 2012 (Table 1 and 2). Seven cases had involvement of the right side, 11 the left and 1 case had bilateral affection (Figure 1 and 2). All patients had flexion contracture of the knee joint with hypertrophic scarring and hypopigmentation. Non-healing ulcers were present in 9 cases. Of the 19 patients in the study, 8 were male. The age range of the study population was 5-56 years (mean 29.6 years). The duration since burn injury ranged from 6 to 15 months (mean 9.15 months). The degree of flexion contracture ranged from 10-120 degrees with an average of 52.75 degrees. All cases were operated under spinal or general anesthesia and underwent incisional or excisional complete release in prone position and coverage with local fasciocutaneous perforator-plus flaps. All cases included a single perforator at the base. Pre-operative Doppler assessment of perforator was done in all but 2 cases, where they were identified intra-operatively. The source vessel was peroneal artery (Figure 3) in 7 cases, superior medial genicular artery (Figure 4) in 5, superior lateral genicular artery in 3, lateral sural (Figure 5) and medial sural in 1 each and saphenous (Figure 1 and 2)/inferior medial genicular artery in 3. The flap dimensions ranged from 11.5x6 to 19x11 Cm. All flaps adequately covered the tissue defect over flexural aspect of knee joint. They were inset in a tension-free manner with maintenance of good contour, color and texture match. The operating time spanned from 75 to 105 min (mean 88.75 min). None of the cases needed splintage and all limbs were mobilised on 7th post-operative day. The total duration of hospital stay ranged from 10-17 days (average 12.1 days). Wound infection and dehiscence of

Table 1: Patient profile and operative details.

Serial no.	Age (years)	Sex	Side	Duration since burn (month)	Degree of contracture	Source vessel	Flap dimension (Cm)	Operating time (min)
1	13	M	Left	9	120	SMGA	19×11	95
2	5	M	Left	6.5	100	SLGA	17×7.5	80
3	35	F	Right	8	50	Peroneal	14×6.5	80
4	27	F	Right	6	10	Lat. sural	17.5×8.5	75
5	56	M	Left	8	45	Peroneal	15×7	95
6	19	M	Left	12	55	SLGA	14×7	100
7	26	F	Left	11	85	SMGA	18×10.5	100
8	34	F	Right	8	70	SMGA	17×10	80
9	33	F	Left	15	25	Peroneal	12×6	85
10	37	M	Left	10	20	Peroneal	14×6	100
11	31	F	Right	7	90	Peroneal	16×7	95
12	23	M	Left	9	35	Med. sural	11.5×6	85
13	18	F	Left	10	40	SMGA	13.5×7	90
14	22	M	Left	11	30	Peroneal	13×7	80
15	31	F	Left	8.5	25	Saphenous	11×6.5	75
16	34	F	Right	8	85	SLGA	15×8	100
17	45	M	Right	9	35	Saphenous	11×6	80
18	37	F	Right	13	70	Peroneal	14×6.5	90
19 left	36	F	Left	7	30	SMGA	18×10	100
19 right	36	F	Right	7	35	Saphenous	15×8	90

SGMA: Superior medial genicular artery flap, SGLA: Superior lateral genicular artery flap.

Table 2: Patients of post-flame burn flexion contracture of the knee joint operated between August 2010 and March 2012.

Serial no.	Hospital stay (days)	Follow up (months)	Early complications	Delayed complications	Aesthetic acceptability
1	14	6		Hypertrophic scar, dog ear correction	Average
2	10	2			Good
3	11	6			Good
4	10	6			Average
5	12	6		Hypertrophic scar	Average
6	11	6			Good
7	17	6	Wound infection	Hypertrophic scar	Average
8	11	6	Minor graft loss	Paresthesia	Average
9	14	6			Average
10	13	6		Hypertrophic scar	Average
11	11	6		Hypertrophic scar	Average
12	10	6		Hypertrophic scar	Good
13	14	6	Minor graft loss		Average
14	15	6	Wound infection		Good
15	10	6		Hypertrophic scar	Average
16	11	6			Good
17	10	6			Good
18	10	6		Hypertrophic scar	Average
19 left	16	6	Tip necrosis		Average
19 right	16	6			Good

Fig. 1: Case no.19: Bilateral contracture: Left-superior medial genicular artery perforator-plus flap, right-saphenous artery perforator-plus flap.

Fig. 2: Case no. 19 post-operative day 10.

Fig. 3: Case no. 3: Peroneal artery perforator -plus flap.

Fig. 4: Case no . 1: Superior medial genicular artery perforator-plus flap.

Fig. 5: Case 4: Lateral sural artery perforator-plus flap.

insetting sutures occurred in 2 cases. Only one case of superior medial genicular artery perforator-plus flap developed marginal tip necrosis. There was no venous congestion in any flap. All local complications were managed under local anesthesia with debridement and secondary suturing or healing by secondary intention. There was minor graft loss over the donor site in 2 cases which were treated conservatively. Apart from a single case of superior medial genicular perforator-plus flap with paresthesia over the antero-medial thigh, no other case had any significant evidence of collateral damage like distal limb edema, sensory loss or muscle weakness. All patients were

followed up for 6 months except one who was lost to follow up after 2 months. 8 cases had some evidence of hyperpigmentation, induration and/or hypertrophic scarring over the grafted area. However, since none of the patients had any graft over the flexural aspect of the knee, there was no incidence of recontracture and hence, no need for reoperation. The flaps provided long-term stable pliable coverage over popliteal fossa with good color and texture match and maintenance of contour. The flaps were not bulky and only one patient desired revision surgery for dog-ear correction which was accomplished on an outpatient basis. All the patients at 6 months follow-up were satisfied with the function and aesthesis of the limb. They were able to maintain unassisted symmetrical upright posture, bipedal locomotion and could squat without difficulty. Apart from 3 patients the rest were able to sit cross-legged on the floor without much difficulty.

DISCUSSION

The contribution of perforators in flap circulation was first suggested by Fujino in1960.[19] Perforator flaps were later developed by Koshima[9,10] and Kroll and Rosenfield.[20] According to Taylor and Palmer's[21] concept of angiosome (1987) almost all tissues of an angiosome can be harvested on one adequate perforator. Such perforators originate from one of the main axial vessels, course through muscle or septa, pierce the fascia and ramify in suprafascial level within subcutaneous fat . Perforator-plus flaps were conceptualized and the nomenclature coined in 2005.[13] The terms perforator-plus and perforator-sparing flaps have been used interchangeably for the same flap design.[16] In classical rotation design the moving tip is under tension if donor defect is closed primarily. This can be prevented by designing oversized flaps or making a back cut from the existing pivot point into the base. However, this might compromise the vascularity of conventional flaps. Inclusion of a known or identified perforator[16] in the base allows greater freedom of back cut which shifts the pivot point closer to the defect and facilitates tension free inset. This phenomenon is applicable to any design of peninsular flap and is the basis of perforator-flap harvest.[22] The peninsular design prevents kinking of perforator vessels and improves venous outflow through the pedicle. Perforator-plus technique is being used in various conditions from lower limb trauma to pressure sores.[15] Evaluation of a series of different perforator-plus flaps for reconstruction of post burn flexion contracture of knee could not be found in the published literature till date. There is no conclusive evidence in literature regarding the safe limit of harvest of perforator or perforator-plus flaps. However, it has been noted that there is a six-fold higher chance of islanded perforator flap failure if the length is more than one-third of the total limb length.[23] It can be postulated that larger dimensions of perforator-plus flaps can be raised than the corresponding islanded perforator flaps due to the dual blood supply. The knee joint has a rich vascular plexus around it which gives rise to many prominent perforators and connects the femoral vessels above with the popliteal and tibial vessels below. An average of 93 perforators from 21 vascular territories supplied the skin of lower extremity. The mean diameter and area supplied by one perforator is approximately 0.7 mm and 47 Cm^2 respectively.[24] Perforator-plus flaps may be designed from various aspects of distal thigh and proximal leg to resurface the tissue defect over popliteal fossa created by contracture release. The antero-lateral thigh flap is based on perforators from the descending branch of lateral circumflex femoral artery which are clustered within a 3 cm radius of the midpoint of a line joining anterior superior iliac spine and superolateral patella. The descending branch anastomoses with the superior lateral genicular artery which allows a distally - based flap to be harvested with the pivot point 3-10 cm above the knee joint.[25] The anteromedial thigh flap is based on a major perforator from the rectus femoris branch of the descending branch of lateral circumflex femoral artery which is present in 51% individuals. It has a musculocutaneous course through rectus femoris in 34% cases, while the rest are septocutaneous. The perforator is located about 3.2 cm medial to the midpoint of line joining anterior superior iliac spine with superolateral patella.[26] Cutaneous perforator of superior lateral genicular artery is located within a triangle bounded by the superior border of lateral femoral condyle, anterior border of short head of biceps femoris and posterior border of vas-

tus lateralis.[27] It is located about 7.4 ±2.77 cm above the lateral femoral condyle.[28] In 60% cases it traverses the lateral intermuscular septum of thigh while in the rest it passes through biceps femoris.[6] The saphenous branch of descending genicular atery originates 13 cm above the medial joint line and courses along a line joining anterior superior iliac spine and medial tibial condyle. Here the vessel traverses deep to the sartorius and gives septocutaneous perforators on either side of the muscle. The terminal branch of this artery anastomoses with collateral vessels around the knee like inferior medial genicular artery, which forms the basis of reverse flow distally based flaps.[29] The cutaneous perforators of superior medial genicular artery is located in a small triangle bounded by superior border of medial femoral condyle, anterior border of adductor magnus and posterior border of vastus medialis.[30] Medial and lateral sural arteries originate from the popliteal artery. The 1-5 medial sural artery perforators were detected in 100% cases in an Asian population. But lateral sural artery perforators were absent in 57% cases. These perforators are located between 5 cm above and 17.5 cm below the popliteal crease within a range of 0.5 to 4.5 cm from the midline raphe of gastrocnemius.[31] The vascular axis of posterior tibial artery lies along a line ~4.5 cm medial and parallel to the line joining tibial tuberosity and midmalleolar point.[32] Septocutaneous perforators arising from it arranged in three clusters, the most proximal of which is 3.6-10.8 cm below the joint line.[33] The peroneal artery perforators[34] are situated along an oblique line behind the posterior border of fibula along the intermuscular septum between soleus and peroneus longus. Proximally they are 0.25 cm away while distally 1.7 cm behind the posterior fibular margin. Based on this anatomic knowledge of the perforator distribution around the knee joint and popliteal fossa robust and pliable perforator-plus flaps can be harvested to cover tissue defects following surgical release of knee contracture. With the advent of freestyle perforator flaps[35] the applicability of perforator-plus flaps can be further broadened with lesser restrictions on flap axiality and design. However, the maximum safe dimension of harvest of such flaps has to be ascertained.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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