The role of pedicled abdominal flaps in hand and forearm composite tissue injuries: Results of technical refinements for safe harvest

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ABSTRACTS

We evaluated the outcome of new technical refinements in abdominal flap coverage of major defects in upper limb for its reliability and safety. 68 patients were assessed for indications, additional procedures, complications and DASH questionnaire evaluation at the end of a year.

The mean size of flap was 56 cm² (range 6–250 cm²). Median DASH score was 11.5 (range: 0–63). Hand stiffness was observed in 39% of patients. However, this was absent in whom prophylactic pinning of metacarpophalangeal joints were done in James position. Abdominal flaps give satisfactory results in hand injuries. Competent hand therapy program is essential to get best results.

1. Introduction

Pedicled abdominal and groin flaps were very popular in the 70s and 80s to cover hand injury defects.^{1,2} They have been replaced by free flaps in the recent times due to the disadvantage of cumbersome positioning, two-stage procedure, increased hospital stay and delayed hand therapy leading to stiffness.^{1–4} However pedicle flaps continue to have a role with new refinements even in centres with microsurgery facilities with specific indications like electric burns, children below two years of age and preparation for future vascularized toe transfer.³ Considering the large volume of patients presenting with variations in type, level, duration and contamination of injury, the aim of the operating surgeon would be to ensure primary wound healing within an optimum time frame with a safe and reliable procedure. Free tissue transfer is an attractive option in such a scenario but the consequences of failure can be devastating as most of our patients don't have health insurance.⁵ Literature supports long term outcomes of successful pedicled flaps which are equal or even better than free flaps.⁴ Due to these reasons abdominal and groin flaps continue to be the workhorse flaps in the developing world as well as at our centre for major hand injuries with composite tissue loss. We present a prospective study of upper limb injuries requiring a refined technique of abdominal and groin flap coverage, with an aim to assess clinical characteristics and the functional outcome.

2. Methods

68 patients who underwent abdominal flap surgery during 2012–2017 were analyzed and interviewed in this prospective study. The indication was wound defects in the hand and forearm exposing vital structures for which loco-regional flaps were not feasible. The mechanism of injury, associated injuries, areas of upper limb involved, the various reconstructive procedures done during abdominal flap surgery or later and the complications were assessed. Informed consent was taken from all the patients in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Condition of the flap and donor site along with functional outcome using the DASH questionnaire assessment was done during follow-up at a minimum of one year.

2.1. Abdominal flap procedure

Radical debridement was done for all wounds and covered by a negative pressure wound therapy (NPWT) dressings unless there were features of vascular injury. After 48–72 h, the wound is covered with abdominal flap. We fix the metacarpophalangeal joints of fingers in 90° flexion to prevent extension contracture in composite defects on the dorsal side of hand and forearm. The pedicle is based on superficial inferior epigastric (SIEA), superficial circumflex iliac (SCIA) and

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Fig. 1. a) shows the general territory of various cutaneous vascular territories of the abdomen Red arrow points to the SCIA and the red shadings shows its territory, blue arrow points to para-umbilical perforators and the 2 regions of blue shading showing its territory as infra/supra-umbilical pedicle, green arrow points to SIEA and green shading its territory. b) blue shade region shows the combined territory of SCIA, SIEA and SEPA (yellow arrow) – a very large flap can be harvested to cover both sides of forearm and hand. c) shows the combined territory of SIEA and para-umbilical perforators – this can cover large defects of forearm and elbow. d) bilateral territory of SIEA and SEPA – to cover large defects of hand and forearm. . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

superficial external pudendal (SEPA) arteries for dorsal and para-umbilical perforators (PUP) for volar wounds or a customized combination of these territories were captured in case of large circumferential wounds (Fig. 1a–d). The flap in our cases extended beyond the flanks in the posterior axillary line and proximally up to the level of 9th intercostal space and often crossing the mid-umbilical line to the contralateral side for large flaps (Fig. 1a–d).

3. Result

68 patients were assessed from 2012 to 2017. 58 of them were males (85%). The mean age was 32 years (range 9–73 years). Most of the injuries were due to motor vehicle (40%) and industrial (37%) accidents. Median duration of delay between admission and abdominal flap surgery was five days (range: 1–36 days). Most of these injuries involved skin defects either in the dorsum or volar side of hand and forearm or both sides (Table 1). The mean size of the abdominal flap was 56 cm² (range - 6–250 cm²). The smallest flap has been for multiple digit finger tips injuries (3 × 2 cm) and the largest one for circumferential defects in

the hand and forearm (25 × 10 cm) (Fig. 2a–c and 3a–e). Donor area skin grafting was required in 57 (84%) patients.

Secondary procedures were done in 47 (69%) patients (Table 2). Depending on the severity of the injuries, patients underwent surgery multiple number of times with an average of 5.1 procedures/patient.

In cases with extensive dorsal composite tissue loss involving hand, wrist and forearm including first web space, we prophylactically keep all the metacarpophalangeal joints of fingers in 90° flexion and the first CMC joint in full abduction using Kirschner's wires (Fig. 4a–h). This was done in 22 patients (32%). This was not done for palmar of digital defects as size of the original defect decreases in the flexion.

Flap delay was done in 18 (26.4%) patients who required tubed flaps and for wider pedicles where the length breadth ratio is less than 1:1.5. Mean duration of time between abdominal flap surgery and flap division was 22.1 days (range 20–35 days).

68 patients were followed up for a mean duration of 27 (± 1.6) months (range 12–60 months). The overall Median DASH score was 11.5 (range: 0–63). Among the 21 patients in whom the flap was done with or without primary repair of the underlying soft tissues (bone, tendon, nerve) the scores were better at 8.1. In 47 patients who underwent secondary reconstruction later, the DASH score was 14.9. Subjective evaluation of pain at the affected and donor site showed the presence of discomfort affecting the activities of daily living in 43% of our patients.

Marginal flap necrosis, which represents necrosis at the distal edge leading to poor and delayed wound healing for more than two weeks occurred in 15 patients (22%). Seven of them were observed at the site of final flap inset at the time of division out of which four of them were observed even after flap delay. Most of them healed after regular dressing or sutured secondarily after debridement. Partial flap necrosis which represents full thickness skin loss up to 1/3rd area of flap occurred in five patients (7%). This was observed by 72 h and in all of them, the flap was debrided on the 7–8th post-operative day and advanced with minor adjustments and split skin grafting in the non-critical areas. These flaps were subsequently divided at three weeks and healed satisfactorily. 13 patients had infection after the flap surgery which was managed with debridement and antibiotics.

Post-operative finger stiffness was noted in 27 patients (39%). Majority of these involved the metacarpophalangeal (MCP) (17 patients) and the rest involved the interphalangeal joints (IP). None of them were immobilized at MP joints with K-wires in the position of safe immobilization. In contrast, 22 patients underwent fixation this way

Table 1

Distribution of the skin defects involving the hand and forearm with involvement of stiffness of fingers.

Region of upper limb involved	Compartments affected	Number of patients (68)			
		Patient with stiffness (27)		Patient without stiffness (41)	
		MP joint (17)	IP joint (10)	K wire for MP joint not used (19)	K wire used for MP joint (22)
Hand (31)	Dorsal	2	3	1	13
	Palmar	3	1	2	
	Combined	2	2	1	1
Hand and forearm (22)	Dorsal	5		3	6
	Volar	1	1	1	
	Combined	1		2	2
Forearm (10)	Dorsal	1	1	3	
	Volar	1		2	
	Combined	1	1		
Elbow and proximal forearm (5)	Dorsal		1	4

Fig. 2. Showing the multiple defect in the distal digits (2a) which was covered with small abdominal flaps (2b) and the subsequent results (2c).

Table 2

Additional procedures done apart from the flap cover.

Types of additional procedures	Number of patients	
	Primary procedures done with abdominal flap	Reconstructive procedures after abdominal flap
Fracture fixation with or without bone grafting	49	11
Arthrodesis of PIP joint		8
Split skin grafting	21	2
Pollicization		1
Toe transfer		3
Tenolysis/arthrolysis		14
Tendon repair/reconstruction	35	16
Nerve repair/reconstruction	20	3
Arterial repair	12	
Debulking		22

(Fig. 6a–d). This was kept for 3–4 weeks and removed only at the time of flap division. None of these patient required admission for hand therapy for stiffness later (Fig. 4e–h). Satisfactory range of movement was achieved with average DASH score of 13.2. We observed stiffness in more than 50% of the 22 patients where K wires were not used for MCP

joint in similar type of wounds (Table 1). Out of the 27 patients, 14 (20%) patients were operated in view of persistent stiffness. 10 them were due to contracture of MCP joints for which arthrolysis was done. One of them had rigid swan neck deformity for which proximal IP joint fusion was done. Three of them underwent flexor tendon tenolysis. In all the patients, improvement was observed. Stiffness of the wrist, elbow and shoulder were also noted but all of them were within the functional range.

4. Discussion

4.1. Surgical technique

Though there are many case series on the groin flaps with case reports on the abdominal flaps, an evaluation of results and complications of groin and abdominal flaps has not been well described in large series.^{1–4,6–10} We have followed the guidelines given by Sabapathy et al. in the design of the flaps with minor modifications (Table 3).⁴ Other workers have demonstrated similar approach to thinning of flap where the distal margins are thinned relying on the subdermal plexus of vessels.¹¹ (Fig. 5a–d). This has resulted in a significant reduction of patients requiring debulking when compared to other workers.¹² In contrast to mattress sutures as suggested by Goertz et al. we have suggested simple sutures placed a centimeter apart to prevent venous

Table 3

Key technical differences between our approach and others in the use abdominal flap surgery for upper limb wound cover.

Technical details	Traditional	Sabapathy et al.	Our approach
Recipient preparation	Thorough debridement, syndactyly if multiple digits involved, primary repair of tendon, nerve, bone in the absence of defect Generally secondary reconstruction in the presence of defects of tendon and bone	Primary reconstruction of defects of bone, tendon possible	K-wire fixation of the MP joints; plan for secondary reconstruction in the presence of defects of tendon or bone
Donor preparation	Based on one axial vessel territory	Try to include 2 territories	
Size of the flap	Flap cannot extend beyond watershed line of midline, proximal to umbilicus and midaxillary line	Flaps can extend beyond these lines to include two or three axial vessel territory	
Thinning	Done at the margins	Bevel the fat at the skin edge of flap	The Scarpa's layer is excised along with thinning at the edge up to 2 cm leaving only a thin layer of fat covering the dermis
Tubing of pedicle	Done	Not done. Left open as it increase the area available for flap	
Suturing and inset	Mattress sutures	Simple sutures at least a centimeter apart	
Donor abdomen closure	Usually closed primarily by undermining the edges	–	Liberal use of skin graft with bolster dressings
Delay	Done at 3 weeks by either dividing the axial vessel with partial division of the flap	Done by dividing the axial vessels	Done by dividing the axial vessel with 1/3 partial division at either side of the flap at 2 weeks
Partial necrosis	Excised at the time of division and then allowed to granulate with subsequent cover with split skin graft. Alternate flap done if involving critical area		Part is allowed to demarcate by 5–7 days and excised. It is then advanced to cover the critical area.
Discharge	Patient is admitted for 2–3 weeks till flap division	–	Discharged in 5–7 days time with customized Velcro straps
Division	Done at 3 weeks		
Secondary Thinning	Done in 2 stage by thinning one half at a time	Done in single stage by making multiple small incisions at the margins

Fig. 3. Showing massive degloving injury of entire left upper limb (3a) which was covered by large bilateral abdominal flaps (3b). note the satisfactory health of flap and donor skin graft healing at 15 days when delay was done (3c). note the satisfactory healing of both the flaps for forearm and hand (3d) and the donor area (3e).

Fig. 4. Friction burn injury with dorsal composite tissue loss (4a) where the MCP joints were fixed in James position (4b, c) before the flap inset (4d). note function after fascia lata grafting (4e-h).

compromise at the edge.³ (Fig. 3b and c) We believe the presence of excess fat with tight sutures may be an important factor in development of marginal necrosis.

In our initial cases we use to undermine the edges at the donor defect, mobilise and close primarily with some tension or at least decrease the defect size to minimize the skin graft requirement. This invariably lead to gaping of wound and subsequent secondary infections in most of the cases needing debridement and repeat skin grafting at the time of division. We now avoid undermining the margins and liberally use skin graft to cover the defect with bolster dressing. In our experience this had resulted in avoiding secondary infections, unhealthy granulations, subsequent scarring and in addition giving a better cosmesis (Fig. 3e). In our series almost 4/5th of the patients underwent

skin grafting at the donor area. This is much more than reported in literature as most of them were related to groin flap with smaller defects where the donor wounds were closed primarily in almost all to 2/3rd of cases.^{3,8,10}

We have relied on only adhesive straps for immobilization with which our patients are comfortable. After the 5th day, this is changed to a customized Velcro based straps which is similar to one suggested by Kamath et al.¹⁸ (Fig. 6a and b) This is easy to apply and allows regular dressing of the wound. In our opinion use of external fixator immobilization to pelvis is not required as cited by other workers.¹³ Unlike reports from literature, almost all the patients are discharged in 5–7 days' time unless there is a complication.³ In spite of apprehension shown by some patients we have observed that the compliance with our

Fig. 5. a) Large flap from SCIA and SIEA region showing a thick flap – 2.5 cm thick (left side showing flap and right side showing the thick fat layer. 5b) The membranous Scarpa's layer (yellow arrow) being separated and removed. 5c) Note the beveling and resection of fat at the margins. We resect up to 0.5 cm thickness and the length can go up to 2 cm 5d) showing the inset with minimal bulk in the flap. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

instruction is satisfactory. This brings down the cost of admission significantly which has been cited as important disadvantage for this flap.³ We have used aspirin prophylaxis till a week after division of flap which has not caused any complications in our patients.¹⁴

Flap delay is necessary in circumferential wounds around the digits where the area of inset is less or near circumferential and in large wounds of the forearm. The delay procedure has been extensively investigated and tested clinically as well.¹⁵ Though some workers have shown no necrosis others have shown various level of necrosis as high as 33% with ischaemic preconditioning.^{3,15} We have followed the traditional approach of delay for a standard random flap which involves 1/3rd partial release on either side of the pedicle.¹⁶ We do the surgical delay after second week and the division is done further after a week.

A major drawback of a flap delay has been the need for an additional surgical procedure and further increase in the duration of immobilization in an unsafe position. The hand therapy program gets held up leading to stiffness. This has been reflected in our patients who undergo this procedure. However, these patients are also the ones who have more severe injuries particularly those with large defects, nerve injuries, bone defects etc. and hence their rehabilitation becomes prolonged as they require more number of procedures with longer healing time needing prolonged hand therapy.

Abdominal flap was used as soft tissue cover alone or with repair of the underlying critical structures in 31% of the cases. In large defects, only the critical area of exposed bone, joint, tendon or neurovascular tissue is covered whereas the rest of areas are covered with split skin grafts. (Fig. 7a–d). These flaps not only can be used as a onetime wound

cover over vital structures in the upper limb but also for its staged reconstruction e.g. 2nd toe to thumb transfer (Fig. 8a–d), tendon reconstruction using fascia lata graft (Fig. 4a–h) and osteoplastic thumb reconstruction. The subsequent average DASH score of 11.5 shows that with this option of wound cover as a part of a routine protocol, we can restore acceptable hand function.

4.2. Complications

Various authors have reported a range from 5% to 40% with respect to complications of wound healing.^{3,6,8,10,12,15} In our series complications were observed more frequently in elderly age group, diabetes mellitus, history of smoking, associated nerve injuries and infections. Similar results has been echoed in other studies as well.^{3,17–20} Goertz et al. have shown a high complication rates in the elderly and in the presence of infections, mechanical trauma and burns.³

We have observed that necrosis occurs in the distal edges of one side of the flap and can happen in three situations: 1) This often appears in cases where the edge has a thick layer of fat. This tissue is vulnerable to ischaemic changes in the presence of tight sutures, 2) When perfusion at recipient suture line may be inefficient. One must freshen the wound margins at second look and check for bright red punctate bleeding to ensure adequate blood supply at that site, 3) Infection in the bed (Fig. 9). Prior radical debridement of the wound is vital for the survival and primary healing of the flap margins (Fig. 7). Complete failures were not seen in our cases as reported in literature.³ This is a significant advantage over free flaps where significant complete failures have been

Fig. 6. Showing the back(a) and front (b) side of the dressing and Velcro straps. Patient ready for discharge on day 5 after flap cover.

reported.^{17–19} Though flap delay has been suggested to decrease the necrosis rates, other studies have not shown the improvements with delay including ours where four out of seven with flap delay still ended up with marginal necrosis.³ We have observed that the incidence increases in the presence at least two of contributory factors which includes diabetes, extensive contamination, smoking, recipient side vascular injury and Elderly patients.

Wray et al. did not observe flap necrosis when the pedicle division was done in two stages.¹⁰ Their first stage was either ligation of the feeding vessels or full-thickness division of a part of the flap. They do not mention the exact width of flap to be partially divided. We observed that our technique of 1/3 partial division at either side may not be helpful. The technique of division of the feeding vessels has been well described in literature but has not been critically compared with division and partial divisions.^{4,15,16}

Our technique usually involves leaving the pedicle open on the undersurface. Though this has been a source for discomfort in some of our patients in terms of frequent dressings, it has not led to any wound dehiscence or infections in the majority of the patients. There were 13 patients who developed wound infections and they also had similar risk factors as suggested for wound necrosis. All the patients required wound debridement and antibiotics. This has been cited as one of the commonest cause of wound complications.³ There were six patients with necrotizing fasciitis where abdominal flaps were used. Good wound healing was observed in these patients with only one of them showing features of partial necrosis who was a diabetic in the elderly age group.

Stiffness was observed in more than 1/3rd of our patients (39%). We have found it difficult to put our patients on hand therapy during the time of flap inset due to pain and wound care problems. This was

started a week after flap division and continued for 12–16 weeks. This helped in improving the stiffness at shoulder, elbow, wrist and IP joints but patients with involvement of metacarpophalangeal joint were often found not yielding to therapy. Though K wire fixation of MCP joint leads to better range of movements as shown in our series, the same may not be applicable in digital injuries due to technical difficulty as the flexed position may result in significant loss of skin area while positioning the hand. Though objective analysis of hand function has been lacking with relation to flap reconstruction for the upper limb in literature, DASH scores done to assess the hand function in pedicled and free flaps both, have attributed this to the nature and severity of injury rather than the characteristics of the flap.^{3,19,20} Gupta et al. observed in their series of free tissue transfers in the upper limb, that timing of reconstruction did not significantly affect postoperative outcomes.¹⁹ Goertze et al. also showed better DASH scores with groin flap for finger than forearm reconstruction.³ This has been our observation as well. The more severe injuries with composite tissue loss and the risk factors lead to significant stiffness in the hand irrespective of the type of flap necrosis.

4.3. Function

Better results were seen with injuries of digits and dorsum of hand in the absence of injury to the underlying vital structures of tendon, nerve, bone and joints. Predictably similar results were observed in literature as the presence of additional injury to the vital structures delays the recovery time.³ This had reflected in the subjective score as well as more severe the injury, poorer are the results particular in patients with risk factors mentioned earlier. The presence of pain at the affected and donor site with activities of daily living in 43% of the cases

Fig. 7. Degloving injury with friction burns affecting both side of forearm and dorsum of wrist and hand (7a, b). follow up after critical area of exposed wrist joint was covered with flap and rest of area covered with skin graft as the long digital tendons were found intact (7c, d).

Fig. 8. Showing staged reconstruction of radial side crush injury of digits (8a) which was covered with flap initially (8b, c) and later a vascularized toe transfer was done for thumb to restore opposition (8d).

Fig. 9. Showing marginal necrosis at tip of flap. This was debrided and grafted at flap division.

could be attributed to the nature of injury in our series where significant composite tissue loss was observed including nerve injury and the fact that in majority of our patients, skin graft was also harvested.

5. Conclusion

In our opinion Abdominal flaps give satisfactory results in the absence of tendon, nerve, bone and joint injuries. In the presence of risk factors and composite tissue loss, patients should be counselled about the complications related to reconstruction with this option and need for a competent hand therapy program after which satisfactory results can be achieved. Positioning the MCP joints of the fingers in James position using K-wires reduced the incidence of stiffness of these joints. Flap delay by partial division on either side of pedicle was not useful.

Flap failure is rare and most of the complications can be addressed satisfactorily.

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Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

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