Algorithm for salvage of the devascularised upper extremity, with associated soft tissue defect, using the anterolateral thigh free flap

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ABS TRACT

Mutilating upper limb soft tissue defects in the presence of critical ischaemia pose a unique challenge to the reconstructive surgeon. Vascular compromise may not only dictate the time frame in which reconstruction must take place, but also limit available reconstructive options. Salvage of upper extremity injuries is rightly more aggressive than similar injury patterns in lower limb injuries. Functional reconstruction of the upper limb leads to far better outcomes than with a prosthesis while aiming to preserve "the highly desirable facility of tactile sensation". In 1983, the concept of flow-through free flaps was first suggested by Souter, for reconstruction of head and neck defects. In 1991, Costa et al. described the single stage resurfacing and revascularization of two traumatized limbs with a flow-through radial forearm free flap. A recent series by Aggarwal et al. reported the exclusive use of flow-through free Antero Lateral Thigh (ALT) flaps in the salvage of devascularised upper and lower limb injuries.

KEYWORDS
Tissue defect, Antero Lateral Thigh (ALT).

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INTRODUCTION

Mutilating upper limb soft tissue defects in the presence of critical ischemia pose a unique challenge to the reconstructive surgeon. Vascular compromise may not only dictate the time frame in which reconstruction must take place, but also limit available reconstructive options. Salvage of upper extremity injuries is rightly more aggressive than similar injury patterns in lower limb injuries. Functional reconstruction of the upper limb leads to far better outcomes than with a prosthesis[1] while aiming to preserve "the highly desirable facility of tactile sensation".[2] In 1983, the concept of flow-through free flaps was first suggested by Souter, for reconstruction of head and neck defects.[3] In 1991, Costa et al. described the single stage resurfacing and revascularization of two traumatized limbs with a flow-through radial forearm free flap.[4] A recent series by Aggarwal et al. reported the exclusive use of flow-through free Anterolateral Thigh (ALT) flaps in the salvage of devascularised upper and lower limb injuries.[5]

We describe our experience of the use of free ALT flaps in salvaging these devastating injuries, proposing that the flow-through flap should form only one step of the reconstructive algorithm.

METHODS

A retrospective case note review was performed of all patients treated at Ganga Medical Centre Coimbatore, between August 2002 to March 2015, who met both of the following criteria:

1. A brachial artery injury in the arm or a combined ulnar and radial artery injury in forearm
2. A soft tissue defect requiring reconstruction with free tissue transfer,

Due to exposure of neurovascular structures, tendon, bone or implants.

RESULTS

Ten patients met the above criteria, presenting with devascularised upper limbs secondary to one brachial artery injury and nine combined ulnar and radial artery injuries. Nine of the patients were male and one female, with eight sustaining injury to their dominant hand. The median age was 38 years (range 18 - 65 years) and follow up data was available for between five and 18 years (median seven years).

Mechanisms of injury included six road traffic accidents - five motorbikes versus car and one pedestrian versus car; one crush from granite; three machine injuries from a grinding machine, carding machine and conveyor belt.

All patients underwent a full primary and secondary survey in line with Advanced Trauma Life Support principles. On arrival all patients were transferred directly to the operating theatre complex where regional anesthesia, by way of brachial block, was administered. This same method of anesthesia was used for subsequent operative interventions/procedures.

The mean Mangled Extremity Severity Score was 7.2 (Range 4 - 12). Six patients had a score of greater than seven.

At the first procedure, all patients underwent primary debridement, under tourniquet control, followed by skeletal stabilization and primary vascular reconstruction. Two patients had fractures of the humerus, five had fractures of both radius and ulna, and one had an isolated fracture of the radius. Methods of fixation are highlighted in table 1.

	Age (years)	Mechanism	MESS	Ischaemia Time (Hours)	Bony Injury & Fixation	Defect Size (cms)	Revascularisation
1	24	Conveyer Belt	7	<6	Humerus fracture DCP + ex-fix	13 x 12	Vein graft to brachial artery
2	65	RTA	7	6	Radius & ulna fracture DCP	25 x 11	Y shaped vein graft from ulnar artery to common digital arteries of 2nd/3rd webspace
3	31	RTA	11	>6	No bony injury	24 x 10	Direct repair of ulnar artery
4	22	RTA	7	4	Humerus fracture Ex fix	27 x 13	Vein graft to brachial artery
5	40	Grinding Machine	6	<6	Radius & ulnar fracture K-wire fixation	18 x 6	Vein graft to radial artery followed by flow through free flap
6	42	Crush from granite	12	>6	Radius & ulnar fracture DCP	20 X 10	Flow through free flap only (intact anterior interosseous artery)
7	18	Carding Machine	7	1	Radius & ulnar fracture DCP	30 x 15	Arterial graft to radial artery
8	49	Run Over	4	4	No bony injury	30 x 9	Direct repair of ulnar artery
9	46	RTA	5	1.5	Radius fracture K-wire fixation	22 x 8	Direct repair of ulnar artery
10	40	RTA	6	6	Radius & ulnar fracture DCP	20 x 8	Direct repair of ulnar artery

Table 1. Table To Summarise Severity Of Injury Of 10 Cases

Mangled Extremity Severity Score (MESS), Road Traffic Accident (RTA), Dynamic Compression Plate (DCP).

Flow was successfully restored in all ten cases, using interposition vein grafts in four cases, end – to - end anastomoses in three, flow - through free flaps in two and an interposition arterial graft in one. All limbs were salvaged. The longest vein graft was 15 cm in length, for the repair of a segmental brachial arterial defect. One patient required return to theatre at 48 hours for revision anastomosis, with interposition vein graft, having previously undergone primary repair of an ulnar artery injury, which subsequently thrombosed.

All patients had critical soft tissue defects, requiring resurfacing with free ALT flaps at a median time of 48 hours (range 12 hours to 96 hours). Two of these were performed as emergency free flaps at the primary procedure, within 12 hours of admission. In two cases the ALT flap was used as a flow through flap. The remaining

eight flaps were fasciocutaneous in five and musculocutaneous in three, raised with a cuff of Vastuslateralis to manage a dead space defect. The recipient vessel in the single brachial artery injury case was the biceps brachii branch of brachial artery. In all forearm cases the remaining divided proximal end of the non-repaired artery, either radial or ulnar, was used as a recipient vessel. The median size of flap was 238 cm2 (ranging from 108 to 450 cm2), with the largest flap being 30 x 15 cm in dimension. All flaps covered critical structures, but were not all used to reconstruct the soft tissue defect in its entirety. One patient underwent reconstruction of remaining non-critical areas with both local transposition flaps and split thickness skin graft (SSG). Four patients required reconstruction of non-critical areas with SSG. One flap underwent marginal necrosis, which satisfactorily healed with a non-operative course of management. There were no complete flap failures.

Eight out of ten patients had concomitant nerve injuries. Two of these patients had nerve injuries without segmental loss and were directly repaired. The remaining six patients required secondary nerve reconstruction. Other secondary procedures are outlined in table 2.

	Type of anterolateral thigh flap reconstruction	Time to flap (Hours)	Complications	Secondary Procedure	Grip Strength	DASH Score
1	Musculocutaneous	<24	-	Nerve, tendon reconstruction and trapezius transfer	22	61.4
2	Fasciocutaneous	>24	Partial flap Necrosis, healed by secondary intention		4.6	52.3
3	Musculocutaneous	48-72	-	Tendon reconstruction with facia lata	NP	-
4	Musculocutaneous	>24	-		NP	38.3
5	Flow through musculocutaneous + SSG	<24	-	Bone grafting with dynamic compression plate	3	60
6	Flow through musculocutaneous + SSG	>24	-	Flap thinning + free functional muscle transfer	2	63.6
7	Fasciocutaneous + SSG	>72	-	Flap thinning, wrist arthrodesis, median nerve repair with graft	NP	39
8	Fasciocutaneous + transposion flap + SSG	>24	-	Median nerve repair with graft	25.3	22.7
9	Fasciocutaneous	>24	-	Ulnar and median nerve reconstruction	24	20
10	Fasciocutaneous	>24	-	Flap thinning	14	34.1

Table 2. Table To Summarise Results Of All 10 Cases.

Split Thickness Skin Graft (SSG).

Case 1

A 24 year old male sustained a conveyor belt injury to his right upper limb, resulting in a devascularised limb with fracture of the humeral shaft, brachial artery injury, median and ulnar nerve injury and avulsion of the biceps tendon and common extensor origin. His initial management was undertaken at a local hospital, by way of application of an external-fixator spanning the elbow and failed direct repair of the brachial artery. He presented to our hospital within six hours of injury.

On arrival he was noted to have a 15 cm long thrombosed segment of brachial artery with critical distal limb ischemia. The defect was debrided, revealing a soft tissue defect of 30 x 12 cm. The humerus was managed with Dynamic Compression Plate (DCP) fixation and the brachial artery repaired with a reversed saphenous vein graft. During the same procedure the defect was resurfaced with a musculocutaneous free ALT flap, anastomosed to the biceps brachii branch of the brachial artery. Remaining raw areas were resurfaced with SSG. The patient had an uneventful post-operative course and both the limb and flap survived.

The following secondary procedures were performed at two and a half months post injury:

1. Median nerve reconstruction by interposition of sural nerve graft.
2. Medial head of triceps to biceps transfer.
3. Flexor carpi ulnaris to extensor digitorum communis & extensor pollicis longus.
4. Z-lengthening of flexor pollicis longus tendon.

At ten month follow up, the patient had a Disabilities of the Arm, Shoulder and Hand (DASH) score of 61.4. Sensory assessment: No point perceived over right thumb, index and middle finger up to> 15 mm. Static and moving 2PD 5mm over RT ring and little fingers were assessed.

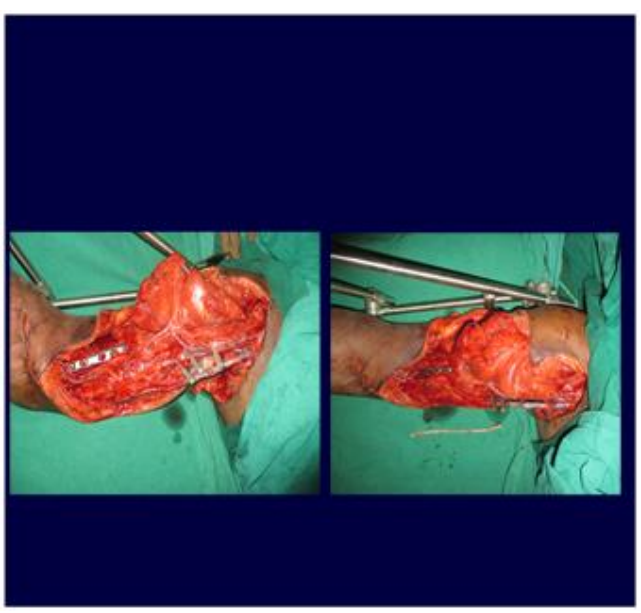

Fig.1A.Depicting Post Debridement Photograph of 24 Years Old Patient With Brachial Artery, Median And Ulnar Nerve Injury With Definitive Bony Fixation.

Fig.1B.Depicting Use of Vein Graft For Brachial Artery Reconstruction And Free ALT Flap For Wound Cover.

Fig.1C.Postoperative Photograph with Functional Assessment.

Case 2

A 40-year-old male sustained a major crush injury to the right forearm from a grinding machine, resulting in a devascularised limb, secondary to injury of both radial and ulnar arteries. Additional injuries included diaphyseal fractures to both radius and ulnar, distal zone five divisions of all long digital flexors, medial and ulnar nerve injuries and an associated composite soft tissue defect. After resuscitation, the patient underwent wound debridement, K-wire fracture stabilization, revascularisation with interposition veingraft to the radial artery, flexor tendon and nerve repair. An immediate emergency flow through free anterolateral thigh flap was performed, with the proximal end of the ulnar artery used as the recipient vessel. The postoperative course was uneventful. Bone grafting and DCP plating were performed as secondary procedures after six months, due to non-union. At 15 months follow up the DASH score was 62.6 and grip strength 2.3.

Fig.2A.Post Debridement Photograph Depicting Distal Zone Five Divisions of All Long Digital Flexors, Medial And Ulnar Nerves And Arteries Injuries And An Associated Composite Soft Tissue Defect.

Fig.2B. Bony Fixation.

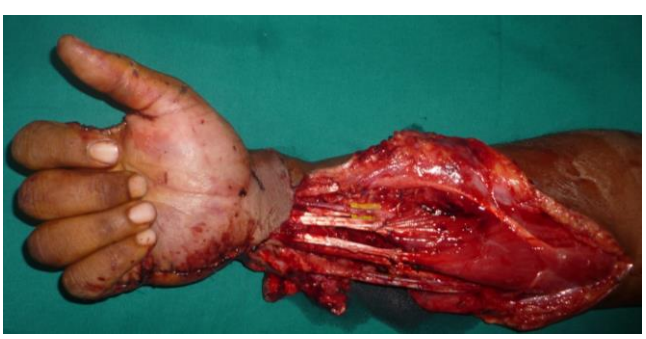

Fig.2C. Radial Artery Repaired with Vein graft, Zone 5 FDS and FDP Repaired and Ulnar and Medial Nerve Repaired.

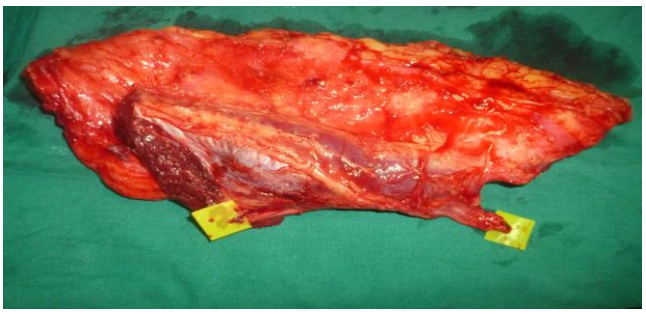

Fig.2D. 20 Cm Flow through ALT FLAP Pedicles Of A Large Caliber (2 To 3 Mm) Koshima [5].

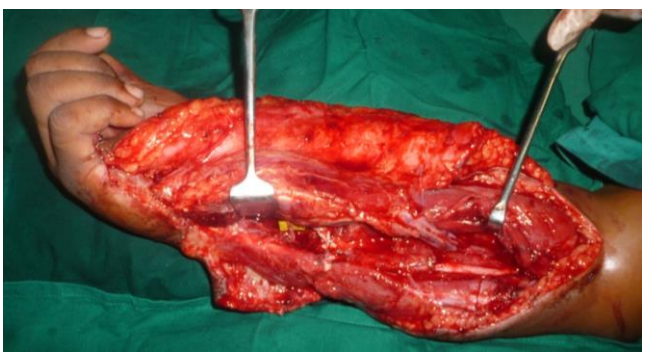

Fig.2E .Intraoperative Flow through ALT Flap.

Fig.2F.Immediate Postoperative Photograph.

Fig.2G. Photograph Depicting Functional Assessment.

Fig.2H. Photograph Depicting Functional Assessment

DISCUSSION

Unless technically impossible, every effort should be made to salvage the upper limb, even in cases of devastating combined vascular, bony and soft tissue injury.

Stepwise algorithm for management of the devascularised upper limb:
1. Wound excision
2. Skeletal stabilization
3. Revascularization by direct vessel repair or vein / artery graft
4. Vascularized soft tissue cover, which should be immediate if a major vessel exposed

Consider use as flow through flap, to augment, not restore, and flow

Vascular defects may be amenable to primary direct repair, particularly in cases of bone loss and subsequent limb shortening. In cases of segmental defects, these can be reconstructed interpositional vein / artery graft and managed together with the soft tissue defect by the use of a flow-through flap.[6] The key point is to achieve good distal flow, which we feel is best achieved with long large calibre vein graft, rather than a flow through flap alone. Flow through flaps were only performed in two cases in this series, as we feel they should not be performed in all cases, rather only when the hand is viable, in order to augment flow. Notably in the similar series by Agrawal et al, all managed with flow through flaps, one of the ten patients required amputation, due to distal necrosis5. This may have been avoided by revascularization with vein graft rather than flow though flaps.

Immediate "emergency" soft tissue cover, with uninjured vascularized soft tissue, at the time of the first procedure, is advocated when a major vessel is exposed, be it native vessel or graft, as per Chen's absolute indications.[7] This was undertaken in two cases in this series.

In this cohort of patients local reconstructive options are unavailable due to either direct trauma or indirectly due to the compromised vascular status of the limb. Regional flaps such as radial or ulnar forearm free flaps, lateral or medial arm free flaps are limited in their use both as they may lie within the zone of injury and as large flaps cannot be raised. Pedicle trunk flaps may not be possible due to the difficulty in positioning the limb in cases of complex skeletal fixation. Distant free tissue transfer may therefore be required.

We feel the ALT flap, described by Song [8,] offers the best option for the following reasons:

1. Large potential skin territory - the largest skin territory

based on a single pedicle of 35x 25cm6.
2. Long pedicle length
3. Potential to be used as a flow-through flap
4. Fascial layer provides good gliding surface for underlying tendons
5. Can be chimeric in design and raised with a considerable amount of vastus lateralis muscle to manage dead space
6. A second surgical team can raise the flap in cases of upper limb reconstruction
7. No intra-operative change in patient positioning is required
8. Easy to re-elevate for secondary procedures

One should however be aware of the potential for a challenging musculocutaneous pedicle harvest and that a small calibre distal descending branch of lateral circumflex femoral artery may rule out its use as a flow through flap. In cases of large flaps, the donor site may require resurfacing with SSG, rather than direct closure.

The free groin flap offers an alternative, with low donor-site morbidity, large potential skin territory and the possibility of including bone and fascia. However, short pedicle length may mean anastomosis out of the zone of injury is not possible.[9]

CONCLUSION

The free ALT flap offers a versatile reconstructive option as part of our proposed reconstructive algorithm for the management of devascularised upper extremity injuries with associated soft tissue defects. Though it may be used as a flow-through flap we feel this should be reserved for augmenting flow rather than the role of critical revascularization.

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