Chinese Journal of Traumatology 21 (2018) 338–351

Contents lists available at ScienceDirect

Chinese Journal of Traumatology

journal homepage: http://www.elsevier.com/locate/CJTEE

Original Article

Reconstruction of post-traumatic upper extremity soft tissue defects with pedicled flaps: An algorithmic approach to clinical decision making

Ravikiran Naalla, Shashank Chauhan, Aniket Dave, Maneesh Singhal*

Department of Plastic Reconstructive & Burns Surgery, All India Institute of Medical Sciences, New Delhi, India

ARTICLE INFO

Article history:
Received 7 January 2018
Received in revised form
24 April 2018
Accepted 1 May 2018
Available online 5 November 2018

Keywords:
Algorithm
Upper limb
Soft tissue defect
Reconstruction
Pedicled flaps
Decision making

ABSTRACT

Purpose: Pedicled flaps are still the workhorse flaps for reconstruction of upper limb soft tissue defects in many centers across the world. They are lifeboat options for coverage in vessel deplete wounds. In spite of their popularity existing algorithms are limited to a particular region of upper limb; a general algorithm involving entire upper limb which helps in clinical decision making is lacking. We attempt to propose one for the day to day clinical practice.

Methods: A retrospective analysis of patients who underwent pedicled flaps for coverage of post-traumatic upper extremity (arm, elbow, forearm, wrist & hand) soft tissue defects within the period of January 2016 to October 2017 was performed. Patients were divided into groups according to the anatomical location of the defects. The flaps performed for different anatomical regions were enlisted. Demographic data and complications were recorded. An algorithm was proposed based on our experience, with a particular emphasis made to approach to clinical decision making.

Results: Two hundred and twelve patients were included in the study. Mean age was 27.3 years (range: 1–80 years), 180 were male, and 32 were female. Overall flap success rate was 98%, the following complications were noted marginal flap necrosis requiring no additional procedure other than local wound care in 32 patients (15%), partial flap necrosis requiring flap advancement or extra flap in 15 patients (7%), surgical site infection in 11 patients (5%), flap dehiscence requiring re-suturing in 5 patients (2.4%), total flap necrosis 4 patients (2%).

Conclusion: The proposed algorithm allows a reliable and consistent method for addressing diverse soft tissue defects in the upper limb with high success rate.

Introduction

Upper extremity soft tissue reconstruction is an extensive topic as a multitude of options exist for diverse soft tissue defects involving shoulder, arm, elbow, forearm, wrist, and hand. Many of the times flap cover is necessary for resurfacing exposed critical structures like tendons, neurovascular structures, bone and to provide supple tissue over joints. The options include local, regional, distant and free flaps. It is well established that free flap option is a versatile single stage procedure facilitating simultaneous reconstruction of other critical structures. It also allows post-operative mobilization and early discharge and return to work.[1] On the other hand, it requires additional resources, workforce, prolonged operating time and carries a risk of total loss of flap.

Pedicled flaps have been the workhorse flaps for reconstruction of the upper limb in many centers across the world. Though the procedure includes multiple surgery, prolonged immobilization, and joint stiffness, refinements in the execution of flap can prevent many of the disadvantages.[2] In some aspects, the outcome is better than free flap reconstruction.[3] Few of the pedicled flaps are well known for both soft tissue coverage and functional reconstruction.[4] Pedicled flaps are the lifeboats when there is a dearth of recipient vessels or in the event of free flap failure.

The reconstructive algorithms exist for specific regions of upper limb[5,6] or general management of upper limb trauma.[7,8] A general algorithm encompassing the whole of upper limb reconstruction with pedicle flaps is helpful in day to day practice.

To simplify the management strategy, we propose an algorithm for reconstruction of upper limb soft tissue defects with pedicled flaps.

* Corresponding author.
E-mail address: drmaneesh@gmail.com (M. Singhal).

Peer review under responsibility of Daping Hospital and the Research Institute of Surgery of the Third Military Medical University.

https://doi.org/10.1016/j.cjtee.2018.04.005

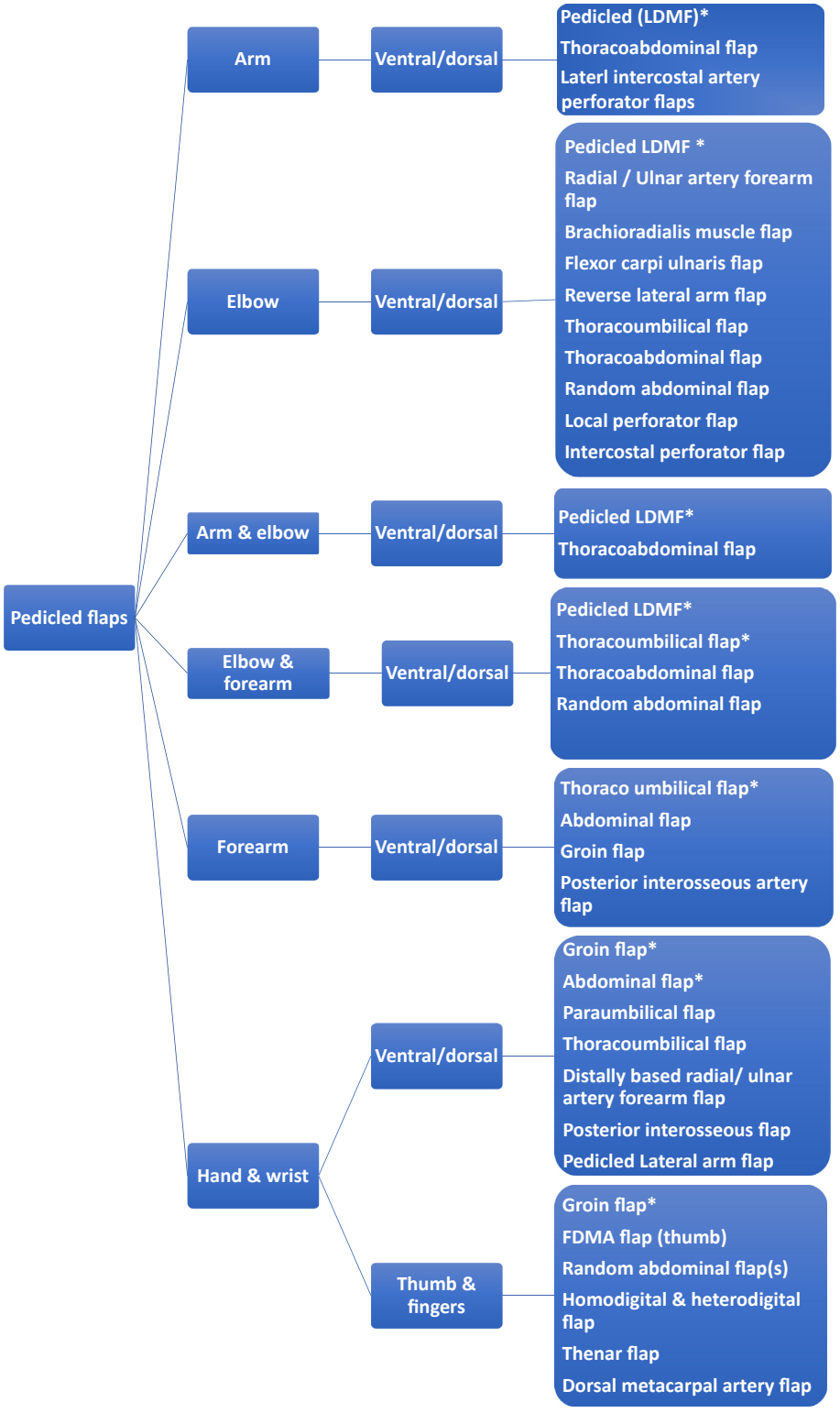

Fig. 1. Flow chart of algorithm for reconstruction of upper limb soft tissue defects with pedicle flaps. LDMF: latissimus dorsi musculocutaneous flap; FDMA: first dorsal metacarpal artery. *Workhorse flap in the author's unit, flaps typed in bold letters indicate that they are used for larger defects.

Methods

Patients

A retrospective analysis of patients who underwent pedicled flaps for coverage of post-traumatic upper extremity (arm, elbow, forearm, wrist & hand) soft tissue defects within the period of January 2016 to October 2017 was performed. The work has been approved by the institutional ethical committee. The inclusion criteria included patients with acute trauma requiring flap cover, implant exposure following orthopedic intervention, resurfacing unstable scars, as a staged procedure for further reconstructive

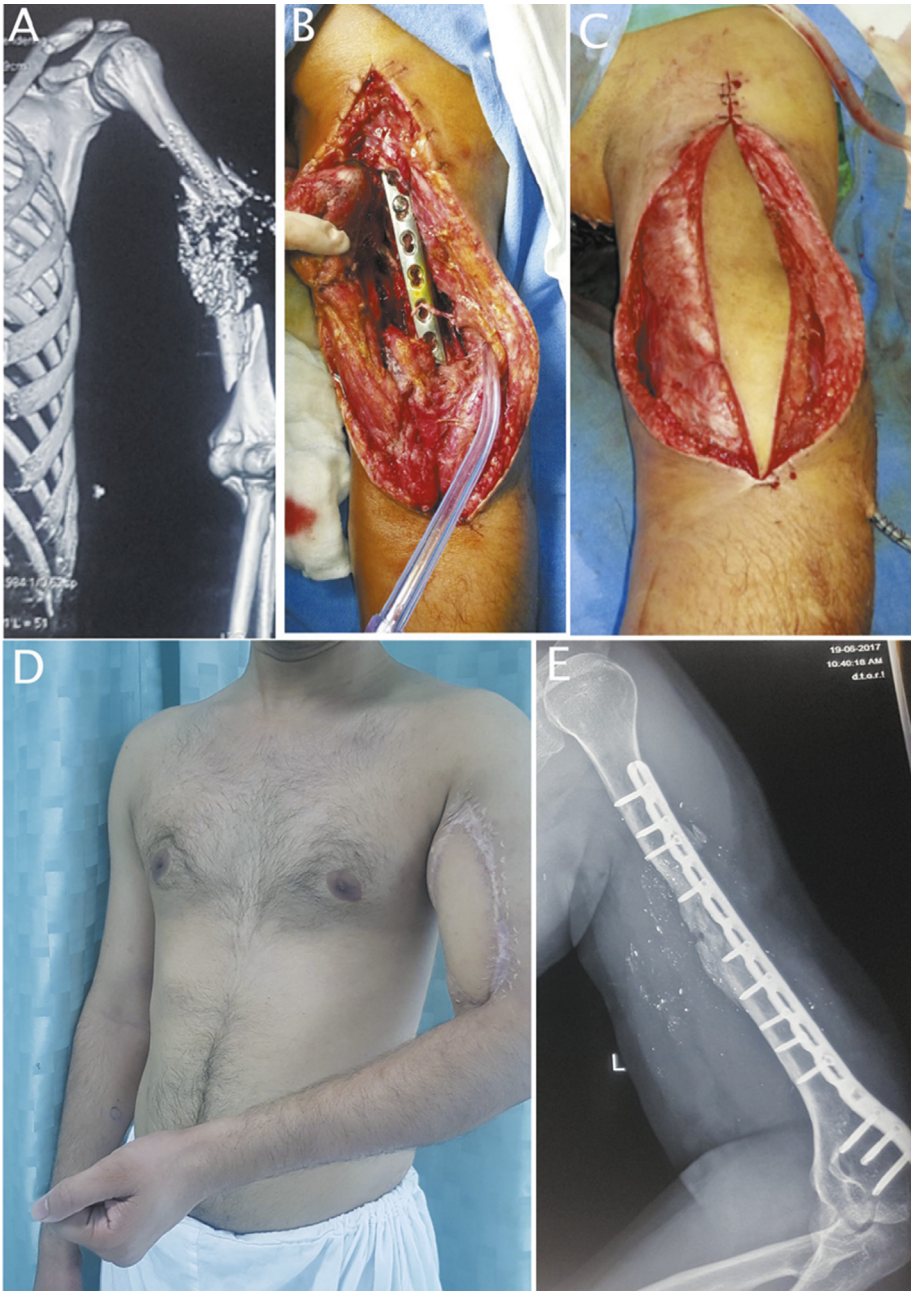

Fig. 2. Images showing coverage of anterior arm defect by pedicled LDMF. A: open comminuted left humerus fracture following gunshot injury; B: wound debridement and humerus fracture stabilization; C: ipsilateral pedicled LDMF before inset; D: well settled flap; E: Well united fracture site. LDMF: latissimus dorsi myocutaneous flap.

procedures, improving function for patients with post-traumatic sequelae. Patients in the study underwent pedicled flap for exposed critical structures like bone, tendon, neurovascular structures, and joint surfaces. Patients who were lost for follow-up were excluded from the study. In general, we prefer radical debridement of the wounds in the acute setting and plan for flap cover in the second stage after 24–48 h. In case of exposed neurovascular structures, immediate pedicled flap cover was done. In selected situations where the wounds are clean flap was performed in the immediate stage in a case to case basis. Once the patients were ambulant, they were discharged to follow in the outpatient department. Flap delay was performed if flap inset was less than 75% of the wound margin or if there was an infectious complication. Flaps were preferably divided at three weeks under local anesthesia for adults and general anesthesia for children. Patients were grouped based on the anatomical location of the soft tissue defect. An algorithm was formulated based on the unit's experience with the pedicled flaps (Fig. 1). The parameters like age, sex, etiology, anatomical location of the defect, flaps performed, complications and functional outcome were analyzed. Marginal necrosis is defined as <1 cm wide necrosis along the margin of the flap. Partial necrosis is defined as >1 cm wide necrosis.

Approach to clinical decision making

Arm defects

Pedicled latissimus dorsi myocutaneous flap (LDMF) is versatile and author's workhorse flap for anterior (Fig. 2), posterior (Fig. 3), and circumferential (Fig. 4), composite soft tissue defects of the arm. Versatility is attributable to its large surface area, vascularized

Fig. 3. Images showing coverage of posterior arm defect with pedicled LDMF. A: Posterior arm defect with exposed hardware and triceps tendon following humerus fracture fixation; B: X-ray showing in situ hardware; C: flap marking; D and E: ipsilateral pedicled LDMF before and after inset; F: Well settled flap and donor site. LDMF: latissimus dorsi myocutaneous flap.

bulky muscle, least donor site morbidity and most important of all is it the significant arc of rotation and distal reach.[4] In most of the clinical scenarios the thoracodorsal pedicle is uninjured, and the flap can be tunneled into the defect facilitating a single stage reconstruction following neurovascular repair or humerus osteosynthesis. It is a lifeboat option to cover exposed neurovascular structures following skin necrosis in case of trans humeral replantation and revascularization.

For lower arm defects thoracoabdominal flap (TAF) is an alternative option.[9] Anteromedial & posteromedial arm defects can be covered, when the flap is based anteriorly and posteriorly respectively. This flap provides fasciocutaneous tissue for coverage, needs two stages.

LDMF and TAF are used for larger defects whereas lateral intercostal artery perforator flaps can be used to cover the lower arm soft tissue defects.[10]

Elbow defects

Pedicled LDMF is the workhorse flap for coverage of large composite soft tissue defects of elbow either in the ventral (Fig. 5), or dorsal surface (sideswipe injuries) (Fig. 6). When the thoracodorsal pedicle is dissected well up to its origin, we have found flap reach is adequate till the elbow without compromise of the distal portion of the flap. Tunnel in the arm should be wide enough to prevent post-operative edema leading to flap compression. The skin paddle in the distal-most part of the muscle is not reliable, and

Fig. 4. Images showing coverage of circumferential arm defect by pedicled LDMF. A: Left arm defect with exposed humerus plate and brachial vessels following mid arm replantation. B and C: ipsilateral pedicled LDMF covering the circumferential defect. LDMF: latissimus dorsi myocutaneous flap.

one must be prepared to cover with skin graft over the muscle in case of skin necrosis. TAF is another excellent pedicled flap option for the coverage of large elbow defects (Fig. 7).[11,12]

For medium to large sized shallow soft tissue defects radial and ulnar forearm artery, axial fasciocutaneous flaps can be used. The drawback of these flaps is donor site morbidity, tendon exposure, sensory abnormalities and sacrificing the artery.[13] In cases of concomitant brachial artery injuries, these flaps are preferably avoided, and distant pedicled flaps are preferred. Other secondary options include random abdominal flaps & thoracoumbilical flap (TUF) as last option.[14]

For small to medium defects over the ventral and dorsal aspects of elbow brachioradialis muscle flap (Fig. 8), [15]flexor carpi ulnaris muscle flap,[16] perforator propeller flaps,[17] reverse lateral arm flap[18] and random abdominal flaps (Fig. 9) can be utilized.

Muscle flaps are better for obliterating the dead space, and they need a skin graft. The advantages of perforator based propeller flaps and reverse lateral arm flaps is that additional skin graft is not necessary and donor site wound can be closed as well.

Arm & elbow

In our experience it is not uncommon to see composite defects of arm and elbow in continuity. These kinds of lengthy wounds are very well covered with pedicled LDMF or TAF preferably as a secondary option as described in the earlier category.

Elbow & forearm

Combined elbow and proximal forearm wounds are well covered by pedicled LDMF (Fig. 10). Complete dissection of the thoracodorsal pedicle and dividing the insertion facilitates the reach of the flap to the junction of middle and distal third of the forearm in our experience. Our observation coincides with the findings of several other series.[19,20] This procedure is technically challenging, and extreme care has to be taken to prevent pedicle damage during dissection and stretch during inset. Elbow flexion can be achieved simultaneously with coverage (Video 1). TAF is another option. For elbow and lengthy forearm wounds involving the distal aspect, either TU

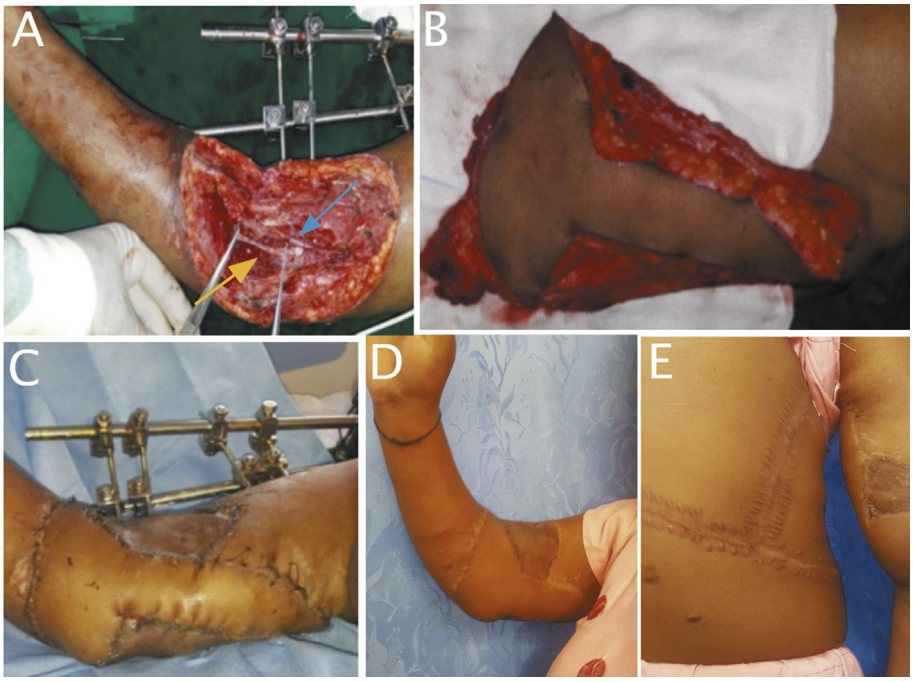

Fig. 5. Images showing coverage of ventral soft tissue defect of right elbow. A: composite defect of with exposed for brachial artery repaired with vein graft blue arrow (contused median nerve yellow arrow); B: ipsilateral pedicled LDMF with inverted 'T' shaped skin paddle for easier closure of donor and recipient wounds; C: early postoperative period image; D and E: well settled flap and donor site. LDMF: latissimus dorsi myocutaneous flap.

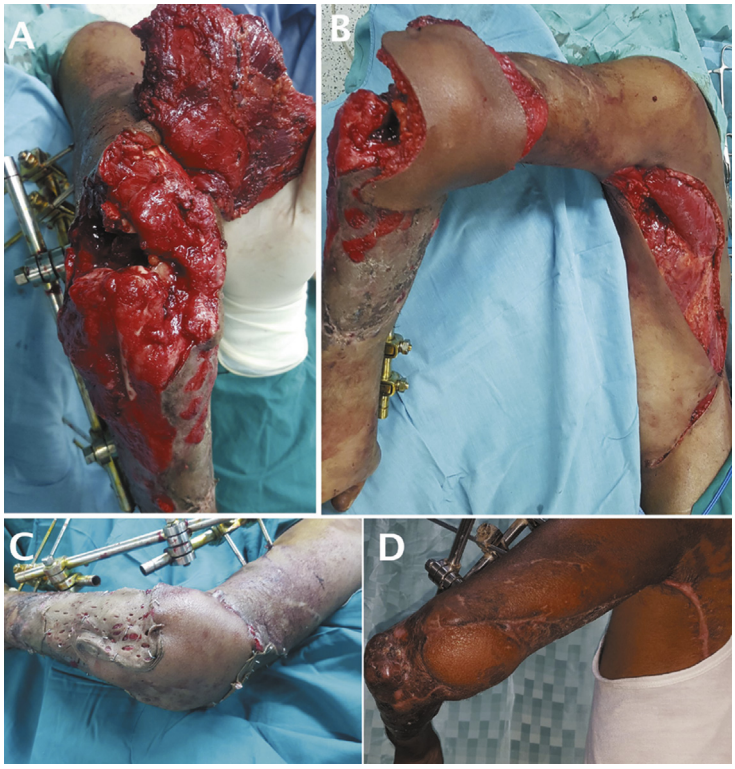

Fig. 6. Images showing coverage of posterior elbow wound by pedicled LDMF. A and B: exposed elbow joint cavity, distal end of humerus and proximal end of ulna following side swipe injury of left elbow and harvested pedicled LDMF before inset; C: after inset and skin grafting of adjacent wound; D: the distal most part of the skin paddle was gangrenous it was debrided and covered with skin graft. LDMF: latissimus dorsi myocutaneous flap.

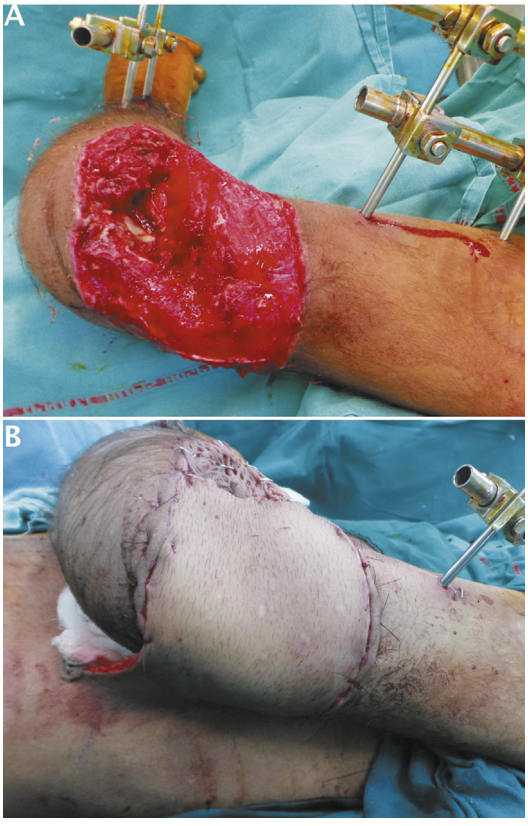

Fig. 7. Images showing coverage of dorsal elbow wound with thoracoabdominal flap. A: exposed elbow joint and large soft tissue defect; B: thoracoabdominal flap inset.

(Thoraco-umbilical) flap or a large randomly based abdominal flap would provide reliable soft tissue coverage.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.cjtee.2018.04.005.

Forearm defects

Ventral & dorsal and combinations defects (Fig. 11) can be very well covered with TU flap.[9] Based on the paraumbilical perforator this axial flap can be harvested from posterior axillary line to umbilicus with greater length to breadth ratio.[21,22] This makes the flap best option for longitudinal and transverse defects as it can provide maximum flap inset and comfortable postoperative positioning as the pedicle is narrow. However, postoperative hypertrophic scarring can be a concern in few patients. Groin flap may be utilized for distal forearm defects. Skin graft at the donor site may be required when large forearm regions needed to be covered, and the positioning of the upper limb be quite uncomfortable in the postoperative period. Mobilization of the hand may be hindered by the bridge segment in case of groin flap, which can be prevented by using a TU flap as bridge segment of the flap is away from the hand. For forearm defects, the groin flap assumes a dependent position and leads to flap edema, whereas TU flap assumes an elevated position.[14] The random abdominal flap may also be used but results in lesser flap inset and raw area over larger bridge segment. Posterior interosseous artery flap sometimes may be used for small to medium sized forearm defects, the dissection may be tedious, and donor site may require skin grafting.

Hand, wrist & fingers

Pedicled groin & hypogastric flaps are our workhorse flaps for coverage of small to large wounds of hand and wrist. Groin flap is versatile for covering volar (Fig. 12), dorsal (Fig. 13), circumferential

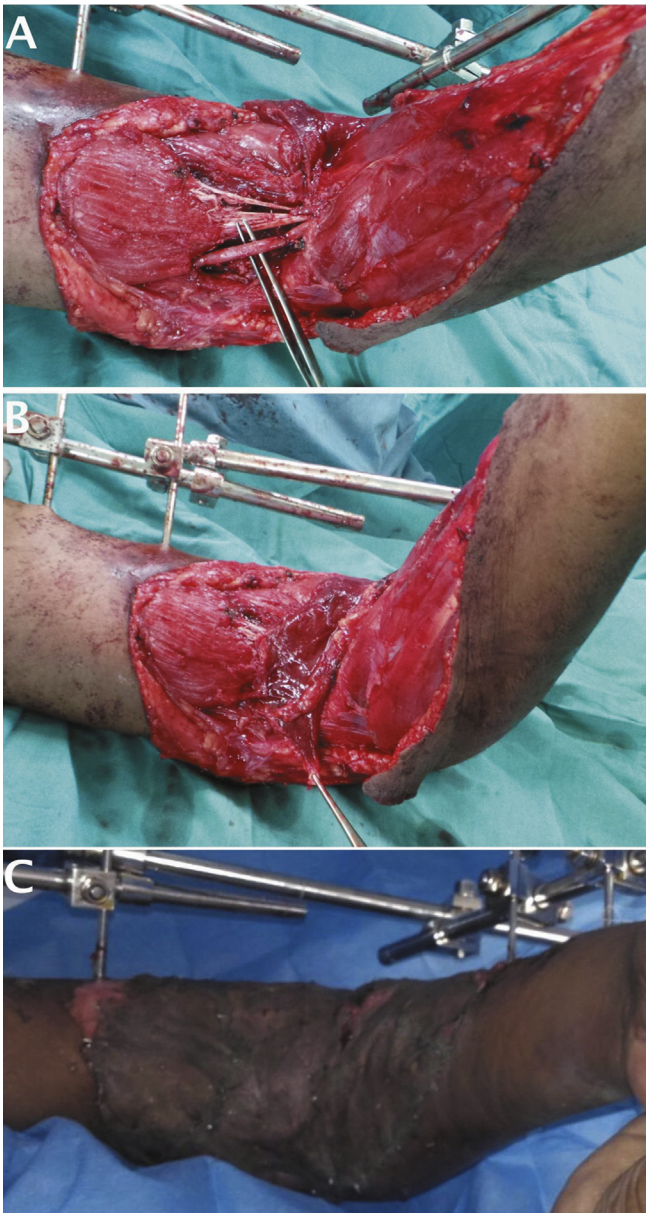

Fig. 8. Coverage of ventral elbow defect with brachioradialis flap. A: elbow defect with exposure of repaired brachial artery, biceps tendon; B and C: coverage with brachioradialis flap and skin graft.

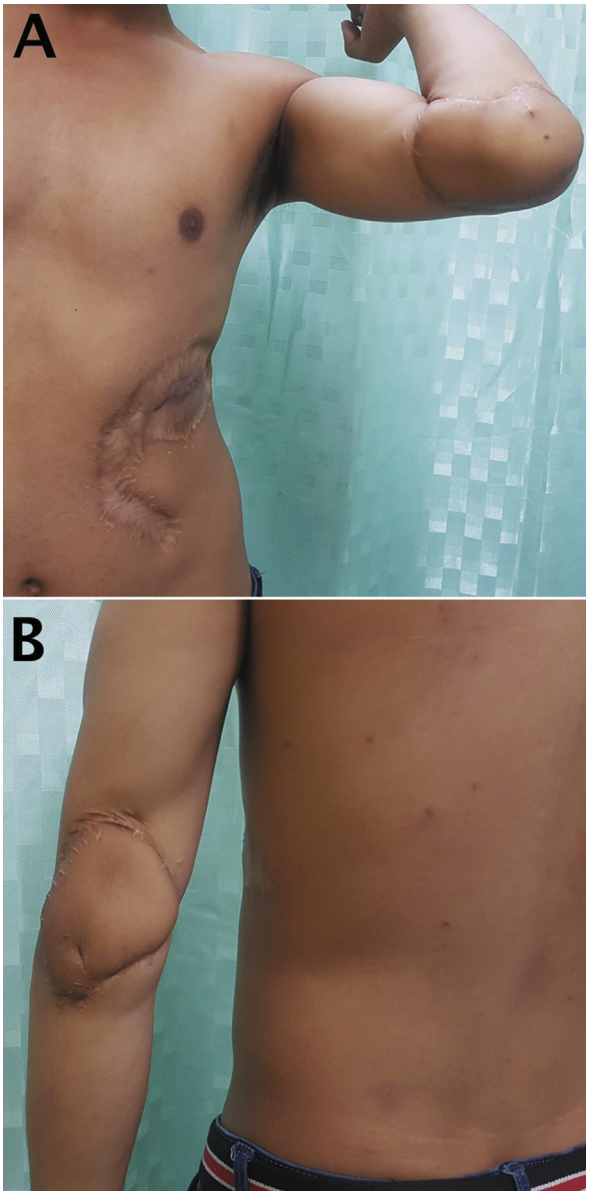

Fig. 9. Coverage of dorsal elbow soft tissue defect with random abdominal skin flap. A: scar at the donor site; B: well settled flap.

wounds.[23,24] The hypogastric flap is an excellent option to cover dorsum of hand & fingers (Fig. 14). Several tips to orient pedicled groin and abdominal flaps have been described.[25] Combining groin, and hypogastric flaps larger defects can be covered. We do not prefer to tube the flap rather; we prefer to keep the base of the flap narrow so postoperative positioning is comfortable and more reliable part of the flap is saved for insetting the flap rather than tubing flap.[3] Groin flap is an excellent option to cover the web space (Fig. 15), amputated thumb and finger stumps for to provide abundant soft tissue for further reconstructive procedures like osteoplastic thumb reconstruction and toe transfer (Fig. 16).[26,27] TU flap may be considered as an alternate flap for coverage of hand reconstruction.

Posterior interosseous flap & reverse radial artery forearm flap (Fig. 17) are well known for reconstruction of hand, wrist & 1st web space.[28] The advantages include a single stage procedure and avoiding post-operative immobilization and associated discomfort. It provides thin and pliable soft tissue. In case of smaller flaps, donor site can be closed primarily. Disadvantages include tedious dissection and its tendency for venous congestion.[29]

For reconstruction of thumb (Fig. 18) and finger soft tissue defects, we prefer groin flap. Harvesting flaps within the groin crease provide thin flaps with highly acceptable hidden scars. For small to medium-sized defects we prefer first dorsal metacarpal artery flap (Fig. 19), Moberg flap for the thumb. Cross finger/reverse cross finger flaps are used for volar and dorsal skin defects respectively.[30,31] Thenar, oblique triangular flaps are routinely used flaps. Reconstruction of thumb and fingertip injuries has been well described.[32]

Reconstruction of & hand finger defects with distant pedicled flaps results in finger stiffness. With dedicated postoperative hand therapy, near normal function can be attained. In many clinical scenarios associated with which require

Fig. 10. Images showing coverage of extensive avulsion injury of left upper limb extending from the mid arm to the distal forearm. A: lost elbow flexors; B: wound was covered with ipsilateral pedicled LDMF; C: Good postoperative elbow flexion and stable wound coverage. LDMF: latissimus dorsi myocutaneous flap.

Fig. 11. Images showing of dorso-radial forearm soft tissue defect with covered with TUF. A: design of TUF; B: TUF after inset; C: well settled flap. TUF: thoraco-umbilical flap.

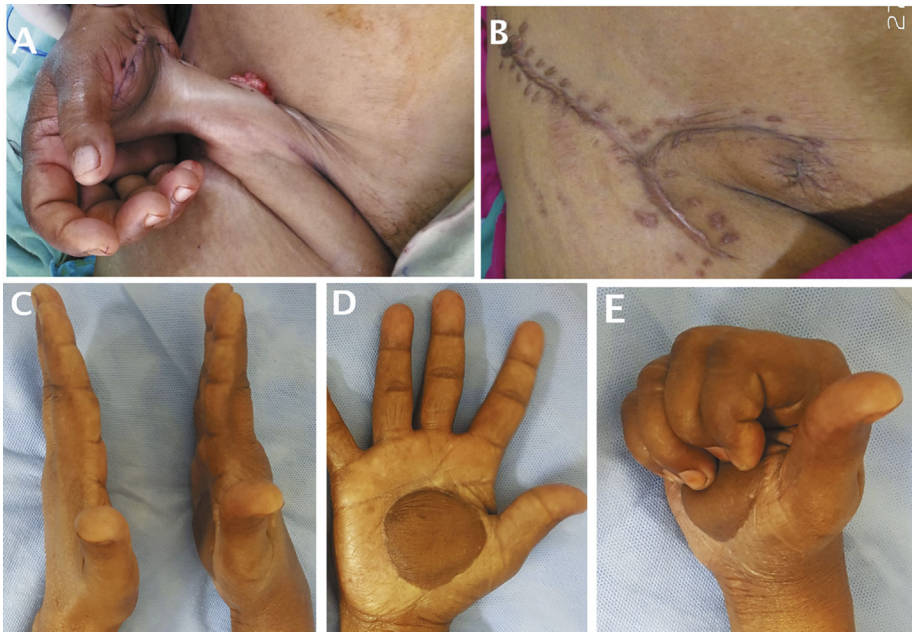

Fig. 12. Images showing coverage of soft tissue defect over the palm with pedicled groin flap. A: groin flap inset; B: donor site; C–E: following single stage defatting well settled flap.

Fig. 13. Images showing coverage of soft tissue defect over the dorsum of hand. A: exposed 5th metacarpal shaft fracture; B: pedicled groin flap insitu; C: well settled flap following division.

Fig. 14. Images showing coverage of soft tissue defect over dorsum of hand and fingers with hypogastric flap. A: Exposed metacarpal fractures and extensor tendons; B: X-ray showing multiple comminuted fracture fixed with K wires; C: left hypogastric flap harvest with pointer at superficial inferior epigastric artery; D: flap inset covering hand and multiple fingers; E and F: well settled flap.

distant pedicled flaps for larger defects co-existing injury bone, joint capsule, tendons lead to residual functional deficits. Sensory recovery in fingers following insensate flap cover is also appreciable, and almost all patients in series gained minimal protective sensation within six months which gradually improved with time.

Results

Two hundred and twelve patients underwent reconstruction with pedicled flaps for upper limb soft tissue defects. Mean age was 27.3 years (range: 1–80 years), 180 were male, and 32 were female. Two patients were lost for follow up and were excluded from the study. All of the patients had a history of trauma, most of them are due to road traffic accidents, work-related injuries, blast injuries and hand injuries sustained at home. The soft tissue defects and flaps performed were grouped according to the anatomical location (Table 1). Flaps were done for resurfacing acute traumatic defects in patients, implant exposure following orthopedic intervention in patients, resurfacing unstable scars in patients, as a staged procedure for further reconstructive procedures in patients, improving function for patients with post-traumatic sequelae in patients. The immediate pedicled flap was performed in 54 (25%) patients for exposure of critical structures or whenever wound was clean according to case to case basis. Two patients underwent latissimus dorsi myocutaneous flap for simultaneous soft tissue coverage, and elbow flexion both of them achieved 130° of elbow flexion and grade 4 power (Manual

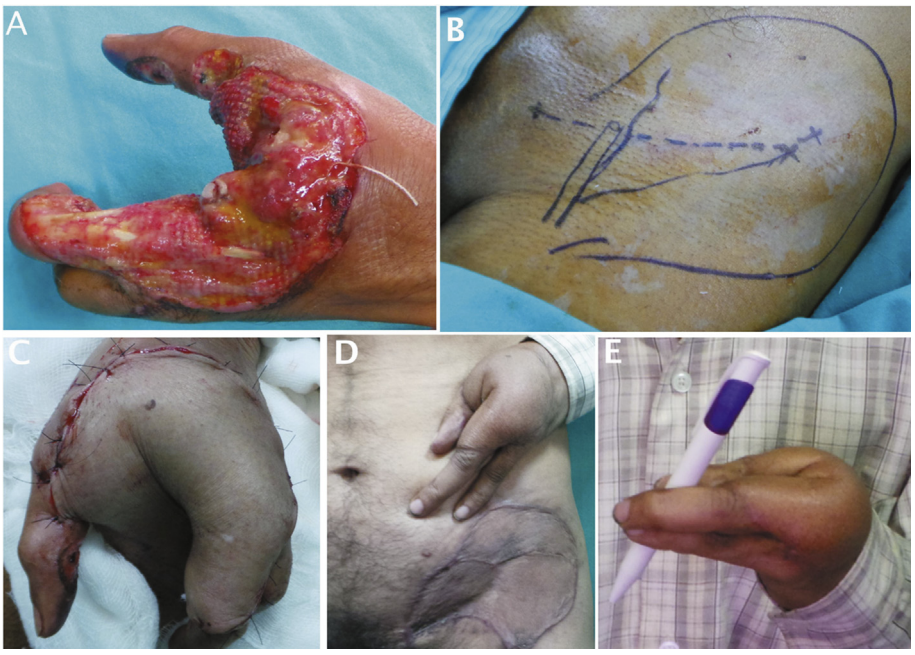

Fig. 15. Images showing coverage of web space and finger defect. A: left hand railway tract injury with exposed metacarpal and flexor and extensor tendons of ring finger; B: marking insitu; C: flap inset; D: well settled flap and donor site skin graft; E: tripod pinch.

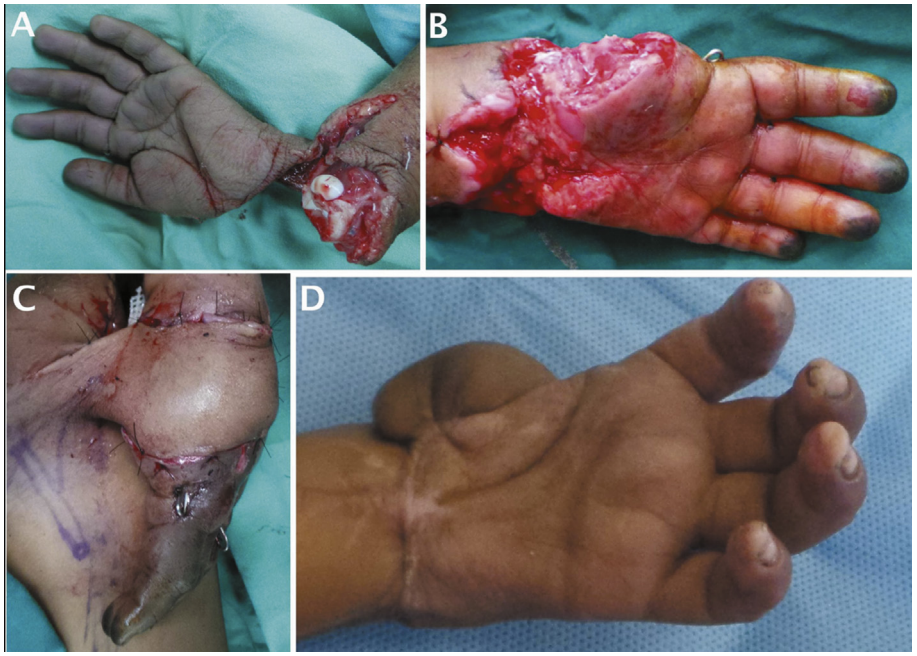

Fig. 16. Images showing groin flap coverage for amputated thumb stump. A: 2-year-old child with near total amputation of left hand; B: following revascularization and repair of tendons and nerves, child sustained gangrene of thumb and sutured skin margins leading exposure of vein graft used to repair the arterial gap; C: coverage of the defect with pedicled groin flap; D: well settled groin flap.

muscle testing grading system). Overall flap success rate was 98%, the following complications were noted marginal flap necrosis requiring no additional procedure other than local wound care in 32 patients (15%), partial flap necrosis requiring flap advancement or extra flap in 15 patients (7%), surgical site infection in 11 patients (5%), flap dehiscence requiring re-suturing in 5 patients (2.4%), total flap necrosis 4 patients (2%). All patients with surgical site infections were managed with antibiotics as per sensitivity. Patients with complete flap necrosis underwent another pedicled following within a gap for a week for mobilization of joints. None of the patients had prolonged lasting shoulder or elbow stiffness due to immobilization for three weeks. None of the patients required free flap due to suboptimal result with pedicled flap. All of the patients had stable soft tissue cover in the follow-up period. None of the patients had long-term problems related to wound healing.

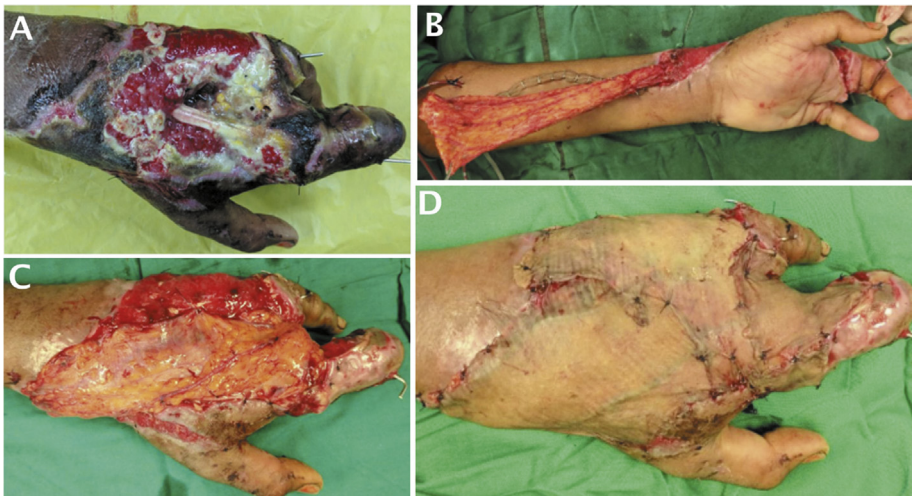

Fig. 17. Images showing coverage of hand wound with reverse radial forearm adipofascial flap and skin graft; A: soft tissue defect over the dorsum of hand following crush injury; B–D: harvested reverse radial forearm adipofascial flap before and after inset and skin graft.

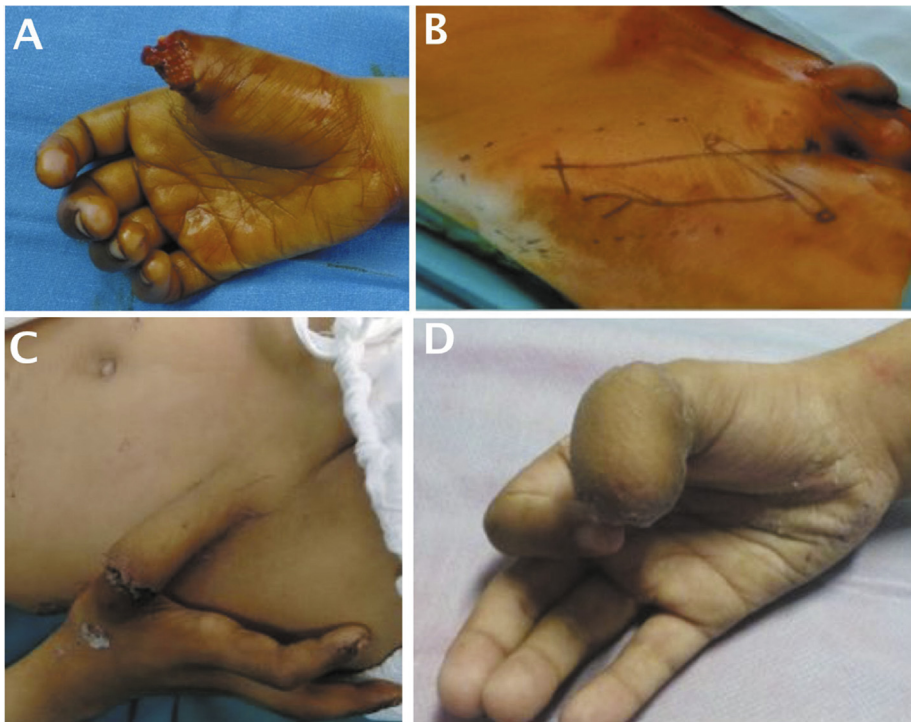

Fig. 18. Images showing tubed groin flap cover over thumb defect. A: Amputation of thumb with exposed distal phalanx; B: marking of groin flap; C: flap after tubing and inset; D: maintained length of thumb following division and inset.

Discussion

Being a high-volume referral level Itrauma center, we manage patients with varied patterns of complex wounds in the upper extremity. We often encounter large wounds when compared to small wounds.

The concept of reconstructive elevator propagates the usage of more complex techniques for the best possible outcomes.[33] For a complex functional unit like upper limb, this concept is very well accepted. However, the choice apparently depends up on the available resources, infrastructure, knowledge, ability of the team, and multiple patient-related factors.

In our day today practice pedicled flaps are workhorse flaps; upper limb free flaps are occasionally done. We routinely perform free tissue transfers for composite tissue defects which warrant emergency vascular reconstruction by mean of flow through flaps. Whenever additional vascular tissue is not necessary pedicled flaps also give good results with less operating time and monitoring.[2] Through this article, we aim to elucidate the region-wise options of pedicled flaps for the upper limb. Several authors have published elaborative description of flap coverage options for elbow,[5,34] forearm,[34] hand,[35,36] fingers[32] and upper extremity as a whole.[3,37] Our study included almost all regions of upper extremity and included all routinely performed pedicled flaps for the upper

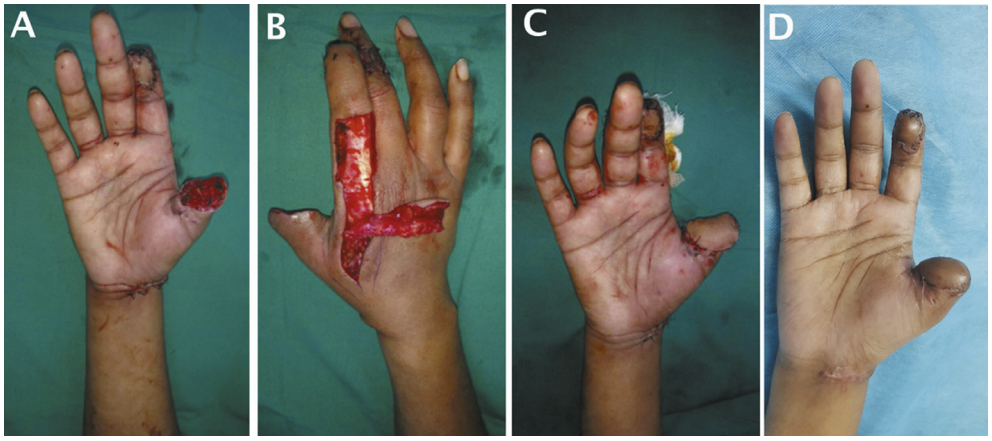

Fig. 19. Images showing coverage of finger defects with pedicle flaps. A: coverage of index finger pulp defect with cross finger flap; B: harvested first dorsal metacarpal artery flap; C: inset of FDMA flap over thumb amputated stump; D: well settled flaps. FDMA: first dorsal metacarpal artery flap.

Table 1
Flaps performed and associated complications grouped according to the anatomical location of the soft tissue defect.

Location	Flap	Number of flaps	Immediate flap	Marginal flap necrosis	Partial flap necrosis	Infection	Dehiscence	Total flap necrosis
Arm	LDMF	4	1	1	–	–	–	–
	TAF	1	–	–	–	1	–	–
Elbow	LDMF	6	2	2	–	1	–	–
	Brachioradialis flap	4	3	–	–	–	–	–
	RAF flap	2	–	–	–	–	–	–
	Random abdominal flap	3	–	2	–	1	–	–
	Local perforator flap	2	–	–	1	–	–	–
Arm & elbow	LDMF	2	1	–	–	1	–	–
Elbow & forearm	LDMF	2	–	1	–	–	–	–
	TUF	1	–	–	–	–	–	–
	Random abdominal flap	3	–	–	1	–	–	–
Forearm	TUF	6	2	1	–	1	–	–
	Abdominal flap	5	1	2	1	–	–	–
	Groin flap	4	–	–	1	–	–	–
	PIA flap	2	–	–	–	–	–	1
Hand & wrist	Groin flap	73	13	10	5	2	2	1
	Abdominal flap	20	5	5	1	1	–	1
	Random abdominal flap	3	–	–	1	1	–	–
	Paraumbilical flap	3	–	1	1	–	–	–
	TU flap	3	–	1	1	–	–	–
	Distally based RAF flap	1	–	–	–	–	–	–
	Distally based UAF flap	1	–	–	–	–	–	–
Thumb & fingers	Groin flap	8	2	–	–	–	2	–
	Tubed groin flaps	21	17	5	2	1	1	1
	Random abdominal flap	5	3	1	–	1	–	–
	FDMA flap	4	2	–	–	–	–	–
	Cross finger flap	17	2	–	–	–	–	–
	Reverse cross finger flap	3	–	–	–	–	–	–
	Thenar flap	3		–	–	–	–	

Abbreviations: LDMF: latissimus dorsi myocutaneous flap; TAF: thoraco-abdominal flap; RAF: radial artery forearm; TUF: thoraco-umbilical flap; PIA: posterior interosseous artery; UAF: ulnar artery forearm; FDMA: first dorsal metacarpal artery flap.

extremity. However, the operative designs and functional outcomes of the individual flaps have not been included as they are available for individual cases elsewhere in the literature and its beyond scope of our article. Principles of upper limb trauma management in general, have been reported by other authors.[7,38] The overall complication rate in our series was 31.4%. However, 11.4% required surgical intervention for optimization, rest of them were minor complications and managed expectantly. Comparisons of complications rates with other studies are difficult as very little literature is available regarding the same. Mishra et al.[14] had reported 39% overall complications in thoracoumbilical flap series and Gupta et al.[39] 27% overall complications in their series of free tissue transfer to the upper extremity.

Many of the patients have bulky soft tissue mass following distant pedicled flap, most of them require additional debulking procedures. Most of the patients in our series accept the outcome of scars following primarily closed donor site. Patients who undergo skin grafting at donor site are the ones who are concerned about the donor site wounds. Most of the patients had a good functional outcome and returned to their routine work unless crippled mangled upper limb injuries.

Limitations of our study are it is a retrospective study, and there is no comparative group, and we have not measured the functional outcome. However, the outcome can not be generalized to a broad spectrum of defects and flaps encountered in this series. The functional outcome results also may be confounded with injuries to

the bone, tendon, neurovascular structures and indeed not related to flap selection. We have not performed all the flaps which we have mentioned in the algorithm. However, one may select appropriate one according to their clinical circumstances.

In conclusion, the proposed algorithm allows a reliable and consistent method for addressing diverse soft tissue defects in the upper limb with high success rate.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cjtee.2018.04.005.

References

1. King EA, Ozer K. Free skin flap coverage of the upper extremity. *Hand Clin*. 2014;30:201–209. https://doi.org/10.1016/j.hcl.2014.01.003.
2. Sabapathy SR. Refinements of pedicle flaps for soft tissue cover in the upper limb. In: Venkataswami R, ed. *Surgery of the Injured Hand*. New Delhi (India): Jaypee Brothers; 2009:131–138.
3. Sabapathy SR, Bajantri B. Indications, selection, and use of distant pedicled flap for upper limb reconstruction. *Hand Clin*. 2014;30:185–199. https://doi.org/10.1016/j.hcl.2014.01.002.
4. Ma CH, Tu YK, Wu CH, et al. Reconstruction of upper extremity large soft-tissue defects using pedicled latissimus dorsi muscle flaps—technique illustration and clinical outcomes. *Injury*. 2008;39(Suppl 4):67–74. https://doi.org/10.1016/j.injury.2008.08.033.
5. Jensen M, Moran SL. Soft tissue coverage of the elbow: a reconstructive algorithm. *Orthop Clin N Am*. 2008;39:251–264. https://doi.org/10.1016/j.ocl.2007.12.009. vii.
6. Horta R, Silva P, Costa-Ferreira A, et al. Microsurgical soft-tissue hand reconstruction: an algorithm for selection of the best procedure. *J Hand Microsurg*. 2011;3:73–77. https://doi.org/10.1007/s12593-011-0046-7.
7. Ng ZY, Askari M, Chim H. Approach to complex upper extremity injury: an algorithm. *Semin Plast Surg*. 2015;29:5–9. https://doi.org/10.1055/s-0035-1544165.
8. Ng ZY, Tan SS, Lellouch AG, et al. Soft tissue reconstruction of complete circumferential defects of the upper extremity. *Arch Plast Surg*. 2017 Mar;44(2):117–123. https://doi.org/10.5999/aps.2017.44.2.117.
9. Farber GL, Taylor KF, Smith AC. Pedicled thoracoabdominal flap coverage about the elbow in traumatic war injuries. *Hand (N Y)*. 2010;5:43–48. https://doi.org/10.1007/s11552-009-9213-8.
10. Acartürk TO. Lateral intercostal artery perforator-based reverse thoracic flap for antecubital reconstruction. *J Plast Reconstr Aesthetic Surg*. 2008;61:e5–e8. https://doi.org/10.1016/j.bjps.2007.11.050.
11. Cannon B, Trott AW. Expeditious use of direct flaps in extremity repairs. *Plast Reconstr Surg(1946)*. 1949;4:415–419.
12. Manahan M, Silverman RP. Chest and abdominal wall reconstruction. In: Guyuron B, Eriksson E, Persing J, eds. *Plastic Surgery: Indications and Practice*. Philadelphia, PA: Saunders Elsevier; 2008.
13. Megerle K, Sauerbier M, Germann G. The evolution of the pedicled radial forearm flap. *Hand (NY)*. 2010;5:37–42. https://doi.org/10.1007/s11552-009-9231-6.
14. Mishra S, Sharma RK. The pedicled thoraco-umbilical flap: a versatile technique for upper limb coverage. *Indian J Plast Surg*. 2009;42:169–175. https://doi.org/10.4103/0970-0358.59274.
15. Patel KM, Higgins JP. Posterior elbow wounds: soft tissue coverage options and techniques. *Orthop Clin N Am*. 2013;44:409–417. https://doi.org/10.1016/j.ocl.2013.03.011.
16. Wysocki RW, Gray RL, Fernandez JJ, et al. Posterior elbow coverage using whole and split flexor carpi ulnaris flaps: a cadaveric study. *J Hand Surg Am*. 2008;33:1807–1812. https://doi.org/10.1016/j.jhsa.2008.08.019.
17. Vitse J, Bekara F, Bertheuil N, et al. Perforator-based propeller flaps reliability in upper extremity soft tissue reconstruction: a systematic review. *J Hand Surg Eur*. 2017;42:157–164. https://doi.org/10.1177/1753193416669262.
18. Tung TC, Wang KC, Fang CM, et al. Reverse pedicled lateral arm flap for reconstruction of posterior soft-tissue defects of the elbow. *Ann Plast Surg*. 1997;38:635–641.
19. Schoeller T, Wechselberger G, Hussl H, et al. Functional transposition of the latissimus dorsi muscle for biceps reconstruction after upper arm replantation. *J Plast Reconstr Aesthetic Surg*. 2007;60:755–759. https://doi.org/10.1016/j.bjps.2006.11.032.
20. Stevanovic MV, Cuéllar VG, Ghiassi A, et al. Single-stage reconstruction of elbow flexion associated with massive soft-tissue defect using the latissimus dorsi muscle bipolar rotational transfer. *Plastic Reconstr Surg Glob Open*. 2016;4. https://doi.org/10.1097/GOX.0000000000001066. e1066.
21. Gutwein LG, Merrell GA, Knox KR. Paraumbilical perforator flap for soft tissue reconstruction of the forearm. *J Hand Surg Am*. 2015;40:586–592. https://doi.org/10.1016/j.jhsa.2014.12.006.
22. O'Shaughnessy KD, Rawlani V, Hijjawi JB, et al. Oblique pedicled paraumbilical perforator-based flap for reconstruction of complex proximal and mid-forearm defects: a report of two cases. *J Hand Surg Am*. 2010;35:1105–1110. https://doi.org/10.1016/j.jhsa.2010.03.036.
23. Krishnamoorthy R, Karthilkeyan G. Degloving injuries of the hand. *Indian J Plast Surg*. 2011;44:227–236. https://doi.org/10.4103/0970-0358.85344.
24. Sabapathy SR, Venkatramani H, Martin Playa P. The use of pedicled abdominal flaps for coverage of acute bilateral circumferential degloving injuries of the hand. *Trauma Case Reports*. 2015;1:25–31. https://doi.org/10.1016/j.tcr.2015.08.001.
25. Bajantri B, Latheef L, Sabapathy SR. Tips to orient pedicled groin flap for hand defects. *Tech Hand Up Extrem Surg*. 2013;17:68–71. https://doi.org/10.1097/BTH.0b013e31827ddf47.
26. Al-Qattan MM, Al-Qattan AM. Defining the indications of pedicled groin and abdominal flaps in hand reconstruction in the current microsurgery era. *J Hand Surg Am*. 2016;41:917–927. https://doi.org/10.1016/j.jhsa.2016.06.006.
27. Sabapathy SR, Venkatramani H, Bhardwaj P. Reconstruction of the thumb amputation at the carpometacarpal joint level by groin flap and second toe transfer. *Injury*. 2013;44:370–375. https://doi.org/10.1016/j.injury.2013.01.012.
28. Rab M, Prommersberger KJ. [Distally pedicled posterior interosseous artery flap for the coverage of defects on the wrist and hand]. *Operat Orthop Traumatol*. 2008;20:111–118. https://doi.org/10.1007/s00064-008-1234-x.
29. El-Sabbagh AH, Zeina AA, El-Hadidy AM. Reversed posterior interosseous flap: safe and easy method for hand reconstruction. *J Hand Microsurg*. 2011;3:66–72. https://doi.org/10.1007/s12593-011-0042-y.
30. Rabarin F, Saint Cast Y, Jeudy J. Cross-finger flap for reconstruction of fingertip amputations:Long-term results. *Orthop Traumatol Surg Res*. 2016;102(4 Suppl):S225–S228. https://doi.org/10.1016/j.otsr.2016.03.006.
31. Atasoy E. The reverse cross finger flap. *J Hand Surg Am*. 2016;41:122–128. https://doi.org/10.1016/j.jhsa.2015.10.008.
32. Tang JB, Elliot D, Adani R. Repair and reconstruction of thumb and finger tip injuries: a global view. *Clin Plast Surg*. 2014;41:325–359. https://doi.org/10.1016/j.cps.2014.04.004.
33. Gottlieb LJ, Krieger LM. From reconstructive ladder to the reconstructive elevator. *Plast Reconstr Surg*. 1994;93:1503–1504.
34. Adkinson JM, Chung KC. Flap reconstruction of the elbow and forearm: a case-based approach. *Hand Clin*. 2014;30:153–163. https://doi.org/10.1016/j.hcl.2013.12.005.
35. Biswas D, Wysocki RW, Fernandez JJ, Cohen MS. Local and regional flaps for hand coverage. *J Hand Surg Am*. 2014;39(5):992–1004.
36. Eberlin KR, Chang J, Curtin CM, Sammer DM, Saint-Cyr M, Taghinia AH. Soft-tissue coverage of the hand: a case-based approach. *Plast Reconstr Surg*. 2014;133(1):91–101.
37. Miller EA, Friedrich J. Soft tissue coverage of the hand and upper extremity: the reconstructive elevator. *J Hand Surg Am*. 2016 Jul;41(7):782–792.
38. Panattoni JB, Ahmed MM, Busel GA. An ABC technical algorithm to treat the mangled upper extremity: systematic surgical approach. *J Hand Surg Am*. 2017;42:934.e1–934.e10. https://doi.org/10.1016/j.jhsa.2017.08.017.
39. Gupta A, Lakhiani C, Lim BH, et al. Free tissue transfer to the traumatized upper extremity: risk factors for postoperative complications in 282 cases. *J Plast Reconstr Aesthetic Surg*. 2015 Sep;68(9):1184–1190.