Thoracoubilical Flap: Anatomy, Technique, and Clinical Applications in Upper Limb Reconstruction in the Era of Microvascular Surgery

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Abstract

Purpose Microvascular reconstruction is the standard of care for salvage of soft tissue defects in complex upper extremity due to their distinct advantages over the pedicled flaps. However, in the era of microsurgery, pedicled flaps have an acceptable significant role for reconstruction of complex soft tissue defects. The authors aim to demonstrate the versatility of pedicled thoracoubilical flap (TUF) in selected clinical scenarios.

Patients and Methods Retrospective analysis of patients who underwent TUF for upper limb posttraumatic reconstruction was performed between January 2016 and October 2017. The demographic details, etiology, wound parameters, clinical circumstances, and complications were recorded.

Results Ten patients were included in the retrospective case series. Out of them, nine of the patients had critical issues, which justified a pedicled TUF over free flap. The critical issues were severe comorbid illnesses ($n = 3$), the paucity of recipient vessels ($n = 1$), salvage of hand replant and revascularization ($n = 2$), circumferential degloving injury to the multiple fingers and palm ($n = 1$), coverage for metacarpal hand ($n = 1$), and extensive scarring at the surgical site ($n = 1$). Mean age was 34.4 years (range: 11–70 years), six of them were males, and four were females. Two patients had infections resulting in wound gaping. One of the patients had flap tip necrosis.

Conclusion Pedicled flaps have a significant acceptable role in this era of microsurgery, and a pedicled TUF is a versatile option for coverage of complex soft tissue defects of the forearm, wrist, hand, and fingers.

Level of Evidence This is a level IV, therapeutic, and retrospective study.

Keywords

- thoracoubilical flap
- pedicled flap
- upper limb
- paraumbilical flap

Introduction

Pedicled abdominal and groin flaps were the workhorse flaps for reconstruction of the forearm and hand before the microsurgical era. Pedicled flaps are still lifeboat options in the event of the paucity of recipient vessels, failure of microvascular surgery, salvage of replantation or revascularization, and limited resource settings.¹

Thoracoubilical flap (TUF) being an axial flap with better length-to-width ratio, it has several distinct advantages over the groin and abdominal flaps.² For forearm and wrist soft tissue defects, higher length-to-breadth ratio facilitates maximum flap inset, and a narrow bridge segment of the flap provides better comfort and facilitates physiotherapy.³ On the other hand, coverage of proximal and mid-forearm defects with groin/abdominal flap is cumbersome.

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Though groin flap is the first choice for coverage of hand and finger defects in authors' practice, the dependent position of the flap often leads to flap edema.³ When groin area is not suitable as a donor site, TUF is an excellent alternative as it assumes an elevated position and is less prone for flap edema. The authors aim to demonstrate the role of pedicled TUF in the current era of microsurgery with its added benefits over the conventional groin and abdominal flaps.

Patients and Methods

Retrospective analysis of patients who underwent TUF for upper limb reconstruction was performed between January 2016 and October 2017. The study has been approved by the institutional ethical committee. Inclusion criteria included patients requiring flap cover for exposed bone, tendons, and neurovascular structures. In the acute trauma setting, the authors prefer to do radical debridement in the first stage followed by flap cover in 24 to 48 hours. In selected situations in which clean wounds are encountered, the authors do immediate flap cover on a case-to-case basis. Patients were discharged once they were ambulant and flap division was done preferably at 3 weeks. Critical analysis was made about the clinical scenarios in which a pedicled TUF was preferred to a free flap for the salvage of upper limb. The demographic details, etiology, wound parameters, clinical circumstances, and complications were recorded.

Vascular Anatomy of Thoracumbilical Flap

The anatomy of paraumbilical blood vessels is well described.^{4,5} Based on these vessels, skin paddles are designed

like spokes of a wheel. The dominant paraumbilical perforator (PUP) on which TUF is based can be found with 2 cm distance from the umbilicus. The flap axis extends from the umbilicus to the inferior angle of the scapula (► **Fig. 1**). The dominant PUP arises from the deep inferior epigastric artery as a musculocutaneous perforator and passes above the fascia of Scarpa to anastomose with the posterior intercostal vessels laterally in the subdermal plexus.⁶

Technique

All the patients were operated upon under general anesthesia with a sandbag placed under the ipsilateral chest. The upper limb wound was debrided radically, and the defect size was assessed. The flap axis was marked between the umbilicus medially and the inferior angle of the scapula laterally. The flap width can be evaluated by pinching the skin. The dominant perforator of the deep inferior epigastric perforator (DIEP) may be marked with Doppler probe usually within 2 cm distance from the umbilicus. The flap is marked by planning in reverse. Flap margins were infiltrated with adrenalized saline (1:200,000) to reduce the bleeding from the edges. The flap was harvested from lateral to medial beginning from the anterior axillary line or midaxillary line depending on the required flap length. One of the flap margins was incised to reach the fascia of Scarpa, and flap was raised below the fascia of Scarpa and just above the external oblique muscle and aponeurosis. In the authors' experience, there was no need to identify the perforator if the flap length was adequate. Flap length can be increased by dissecting perforator deep to the source vessel. The donor wound can be closed comfortably after undermining the skin edges. Flap inset was made

Fig. 1 Image (A) showing marking and vascular anatomy of TUF. DIEA, deep inferior epigastric artery; PUP, paraumbilical perforator; SIEA, superficial inferior epigastric artery. (B) Right lateral image showing the extent of the flap (dotted lines indicate anterior and midaxillary lines).

beginning at the tip followed by the posterior and the anterior marking as per ease of suturing. Beveling of the flap margins was done to facilitate tension-free suturing. Following inset upper limb was immobilized with the help of adhesive tape. The flap was divided at the end of 3 weeks. Flap delay was performed if there was wound dehiscence due to infection.

Results

Ten patients were included in the case series. Out of them, nine patients had critical issues, for which a pedicled TUF was preferred to a free flap for the salvage of upper limb. The critical issues included severe comorbid illnesses ($n = 3$), paucity of recipient vessels ($n = 1$), salvage of hand replant and revascularization ($n = 2$), extensive scarring at the surgical site ($n = 1$), circumferential degloving injury to the multiple fingers ($n = 1$), and coverage of metacarpal hand ($n = 1$). Mean age was 34.4 years (range: 11–70 years); six of them were male, and four were female. The most common etiology included road traffic accident ($n = 6$), postburn sequelae ($n = 1$), nonhealing fasciotomy wound ($n = 1$), gunshot wound ($n = 1$),

and machine cut injury ($n = 1$). The mean size of the wound was 93 cm² (range: 30–240 cm²). TUF was used for coverage of the forearm ($n = 6$), hand ($n = 2$), hand and wrist ($n = 1$), and fingers ($n = 1$). Two patients had infections resulting in wound gaping that required debridement and reinset. One of the patients had flap tip necrosis probably due to crossing the midaxillary line during the flap harvest; additional random abdominal flap was done to cover the exposed area following flap debridement. All the patients attained satisfied stable soft tissue cover. One patient had scar hypertrophy at the donor site, which was managed with conservative measures. All the patients had a satisfactory aesthetic outcome at the donor site. The demographic data, wound and complications details, and critical issues have been tabulated (► Table 1).

Case Series

In the authors' experience, the following are the indications of TUF in the era of microsurgery. Each of them is explained with a clinical example.

- **Paucity of recipient vessels:** A 17-year-old boy presented with a high-voltage electric burn injury to the left

Table 1 Details of the patients included in the case series

Age/Sex	Etiology	Anatomical region	Surface	Critical issue	Complication	Outcome
17/M	Electrical burn	Mid and distal forearm	Volar surface	Paucity of recipient vessels and need for microvascular surgery in a later stage	Nil	Good
70/F	Fasciotomy following acute limb ischemia	Proximal, middle, and distal forearm	Dorsolateral surface	Multiple blocks in the upper limb vessels and severe life threatening comorbid illnesses	Nil	Good
22/F	Trauma	Mid forearm	Ulnar surface	Chronic nonunion of both bones forearm with extensive scarring due to previous surgeries	Wound dehiscence due to infection	Good
46/M	Trauma	Forearm	Ventral-ulnar	Nil	Nil	Good
65/F	Trauma	Forearm	Dorsal	Elderly age with diabetes, hypertension	Nil	Good
21/F	Gunshot injury with subtotal amputation of hand	Distal forearm	Volar	Skin necrosis over the critical vessel repair leading to exposure of arteries	Nil	Good
11/M	Cut injury	Hand and wrist	Dorsal surface	Dorsal skin necrosis following replantation of hand at wrist leading to exposure of repaired veins	Nil	Good
45/M	Trauma	Hand	Volar surface of palm	Failed digital revascularization, chronic smoker, pneumothorax complicating COPD	Wound dehiscence due to infection	Good
20/M	Trauma	Fingers	Circumferential	Circumferential degloving injury of all fingers	Partial flap necrosis	Good
27/M	Trauma	Hand	Volar and dorsal	Coverage of metacarpal hand for future toe transfer	Nil	Good

Abbreviations: COPD, chronic obstructive pulmonary disease; F, female; M, male.

upper limb. The patient was initially managed by serial debridement of all the flexor compartment muscles, tendon, and neurovascular structures followed by skin grafting. In the subsequent follow-up, the wound was healed. He required flap coverage over the volar surface of the forearm for reconstruction of the thumb and finger flexors (either by tendon transfer or functioning free muscle transfer) and reconstruction of the median and ulnar nerves. Computed tomographic (CT) angiogram revealed block in the radial and ulnar arteries with a distal reformation of the ulnar artery with collaterals. Given paucity of the recipient vessels and the potential need for free functioning muscle transfer in future, a pedicled TUF was performed after removal of the existing skin graft (►Fig. 2).

- **Severe comorbid illnesses:** A 70-year-old woman presented with nonhealing fasciotomy wound over the left forearm following acute limb ischemia due to an embolic complication of diffuse axillary artery thrombosis. The patient was also diabetic, hypertensive, and has arrhythmic heart disease. Upon presentation, she had a left forearm wound of 10×7 cm with exposed radius and associated Volkmann's ischemic contracture (VIC). She underwent TUF cover in and attained stable soft tissue coverage (►Fig. 3).
- **Extensive scarring in the operative field:** A 22-year-old woman presented with chronic nonunion of both bone fracture in the right forearm with extruded proximal ulna through the skin the middle one-third of the forearm. Earlier she was treated for both bone forearm open fracture

Fig. 2 Image showing (A) extensive left upper limb wound following fasciotomy and debridement for high-voltage electrical injury. Serial debridement and skin grafting and TUF were done. (B) Well-settled TUF over mid and distal forearm. (C) Donor site hypertrophic scar.

Fig. 3 Image showing (A) nonhealing fasciotomy wound exposing radius in the left forearm. (B) Harvested ipsilateral TUF (dotted line indicates the axis of the flap). (C) Undersurface of the flap and closed donor site. (D) Inset of the flap (long bridge segment comfort in patient positioning).

with external fixation and skin grafting over the associated extensive degloving injury of the adjacent soft tissue. Intraoperatively, there was contamination and significant fibrosis around the fracture site and adjacent skin. The external fixator was applied to the radius, and ulna was fixed with K-wire. The resultant wound was covered with a pedicle TUF. Postoperatively there was flap dehiscence due to infection. Wound margins were debrided, and reinset was done along with treatment of the infection. The patient had stable soft tissue cover in the follow-up period (►Fig. 4).

- **Salvage of replanted hand:** A 11-year-old child presented with total amputation of the right hand at the level of the wrist. Following replantation, skin margins over the dorsum of the hand were gangrenous on the third postoperative day. Debridement of the skin led to exposure of the repaired dorsal veins; hence, immediate TUF was performed to cover exposed dorsal veins. Due to the comfortable position of the hand, postoperative physiotherapy led to a good functional outcome (►Fig. 5).
- **Chronic smoker and chronic obstructive pulmonary disease (COPD) with failed digital revascularization:** A 45-year-old man presented with road traffic accident with subtotal amputation of the ring finger and multiple metacarpal fractures. The ring finger was revascularized and subsequently amputated as it was a failure. The patient developed pneumothorax due to rupture of the bullae secondary to COPD. He was managed with an intercostal chest drain. He had an ulcer over the palm with exposed flexor tendons. He underwent TUF under local anesthesia. Postoperatively he had surgical site infection that led to partial wound dehiscence. The margins were debrided and resutured (►Fig. 6).

- **Circumferential degloving injury in multiple fingers:** A 20-year-old man presented with a circumferential degloving injury to the right index, middle, ring, and little fingers following crush injury to the hand. The crushed fingertips were amputated due to nonviability. TUF was harvested and wrapped around the degloved fingers. The distal portion of the flap was gangrenous probably due to the flap harvest beyond the midaxillary line. The gangrenous portion was debrided, and a random abdominal flap was done to close the defect. The patient had stable soft tissue cover after that. He was planned for syndactyly release on a later date (►Fig. 7).
- **Coverage of metacarpal hand:** A 27-year-old man presented with unsalvageable transmetacarpal amputation of the hand. The patient underwent TUF cover over the proximal metacarpal stump so that it preserves recipient vessels and provides soft tissue base upon which toe transfer can be performed in due course.

Discussion

The versatility of TUF in covering the varied anatomical locations extending from the proximal forearm to fingers is due to its axially imparted by the dominant PUP. The unmatched length-to-breadth ratio facilitates longer inset and freedom of movement of the upper limb. These are the advantages of TUF over other abdomen-based flaps,² and hence preferred for these defects in this series.

It is a well-known fact that free flaps can provide large and reliable soft tissue cover along with the functioning muscle, bone, nerve, and bridge to the segmental defects of the vessels.⁷⁻⁹ These properties make them first line of choice for a better functional outcome. In the current era of microsurgery, pedicled

Fig. 4 Image showing (A) extruded ulna in the middle one-third of right forearm with adjacent scarred and contracted wound following skin grafting. (B) X-ray showing both bone fracture with nonunion. (C) Wound dehiscence following TUF due to infection. (D) Well-settled flap following debridement and reinset.

Fig. 5 Image showing (A) total amputation of the right hand at the level of the wrist. (B) Dorsal skin necrosis following successful replantation. (C) In situ TUF for coverage of the wound following debridement. (D) Stable soft tissue cover.

flaps have an acceptable role and are indispensable in selected clinical scenarios.¹⁰ This has been documented by the experience of several authors with abdominal and groin flaps.^{1,2,10,11}

Since the initial description of TUF by Taylor et al,⁴ many authors have described its clinical utility in various regions of the upper limb.¹²⁻¹⁵ It was termed as paraumbilical flap by several authors.^{2,16,17} Though this flap is well known, the authors aimed to highlight the acceptable use of pedicled TUF in this era of microsurgery.

Use of pedicled flaps in reconstruction of electrical burn injuries is well described. They are the more straightforward alternative to free flaps as the recipient blood vessels may be thrombosed or extensive dissection may damage the established collateral blood flow.¹⁸ The authors selected TUF as it is better over the groin and abdominal flaps for proximal and mid-forearm defects and allows better comfort.²

Pedicled flaps are preferred over the free flaps in frail elderly patients with multiple life-threatening comorbid illnesses. Free flaps are associated with more number of postoperative complications in spite of their success in these particular patients.¹⁹⁻²¹

In the event of exposure of the blood vessels or other critical structure following replantation or revascularization, the pedicled flaps offer a simple solution for the complex issue, radical debridement of the gangrenous skin edges, and cover by a pedicle flap gives good results.²²

Mini free flaps have been described the several authors. They are limited to single- or double-digital defects.^{23,24} Complex circumferential degloving injury to the multiple digits almost always requires a pedicled flap.^{10,25,26} Very rarely total degloving injuries to the hand have been managed with free flaps.²⁷

Fig. 6 Image showing (A) soft tissue defect and exposed flexor tendons following unsuccessful revascularization of the ring finger. (B) TUF in situ. (C) Stable soft tissue cover in the follow-up period. (D) Acceptable donor site scar.

Fig. 7 Image showing (A) folded TUF for coverage of circumferential degloving injury of palm and all finger; gangrenous distal portion of the flap was debrided and covered with random abdominal flap. (B) Stable soft tissue cover over the dorsal surface. (C) Well-settled abdominal flap on the volar surface.

Coverage of amputated stump of the thumb or multiple fingers by pedicled flap is a well-established entity.^{28,29} The pedicled flap preserves the recipient vessels for second-stage toe transfer besides providing stable soft tissue cover and preventing contractures of fingers.

In the authors' experience, the flap success rate of TUF was 100%. Patient 9 developed partial flap necrosis probably due to flap harvest beyond midaxillary line. The flap harvested in this fashion is prone for the distal necrosis.³ Though this flap results in a scar in the abdomen and chest, none of the patients in this series complained as the regular traditional clothing cover them. Occasionally, the donor site scar can be problematic due to hypertrophy as seen in one of the patients. Larger flaps require skin grafting at the donor site, and none of the patients in this series required skin grafting. Groin flap has a distinct advantage over the TUF concerning concealed donor site.

Limitations of this study are less sample size and lack of comparative group.

Conclusion

Pedicled flaps have a significant acceptable role in this era of microsurgery, and a pedicled TUF is a versatile option for coverage complex soft tissue defects of the forearm, wrist, hand, and fingers.

Conflict of Interest

None.

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