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Contralateral Salvage: Strategic Cross-Hand Replantation Following Bilateral Mutilating Injuries

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Rasheedha Begum [1], Valarmathy V. Subramaniyan [1], Swetha Narayanan [1], Shonu Annet Kurian [1], Annapoorani Manoharan [1], Santhoshini Sivaramakrishnan [1], Rajeswari Balakrishnan [1]

1. Department of Plastic and Reconstructive Surgery, Madras Medical College, Chennai, IND

Corresponding author: Rasheedha Begum, rasheedhabegum124@gmail.com

Abstract

Cross-hand replantation is a rare salvage procedure indicated for patients with severe, asymmetric bilateral upper-extremity amputations in whom orthotopic replantation is non-viable. A 26-year-old right-hand-dominant male presented following a high-energy railway accident resulting in devastating bilateral upper-extremity injuries. The left upper limb sustained an unsalvageable mid-humeral crush amputation with extensive neurovascular disruption and segmental bone loss. Conversely, the right distal upper extremity had a mangled hand, including digital auto-amputation and carpal destruction, but preserved a viable forearm stump.

Following multidisciplinary evaluation, the patient underwent emergency heterotopic (cross-hand) replantation of the viable left hand onto the right forearm stump. Skeletal stability was achieved using Kirschner wire fixation, followed by microvascular arterial and venous anastomoses, primary tendon repairs, and coaptation of major nerves. Total warm and cold ischemia time was 9 h. The replanted heterotopic hand survived completely with no postoperative vascular compromise. A structured hand rehabilitation protocol was initiated early, incorporating customized splinting, progressive mobilization, and task-specific sensory and motor re-education. At follow-up, the patient demonstrated functional prehension with meaningful improvement in activities of daily living. He was independent in several routine activities, although assistance was still required for selected self-care tasks.

Categories: Plastic Surgery, Trauma
Keywords: bilateral upper extremity injury, cross-hand replantation, hand rehabilitation, heterotopic replantation, mangled hand

Introduction

Bilateral upper-limb amputations are catastrophic injuries that lead to severe functional disability and psychological distress. The loss of both upper extremities deprives patients of independence in activities of daily living, vocational capability, and social engagement. Whenever technically feasible, replantation remains the primary reconstructive option, as it preserves a sensate autologous limb capable of cortical reintegration and functional recovery.

In exceptional circumstances, one upper limb may sustain an amputation that is unsuitable for replantation, while the contralateral hand is severely mangled and deemed unsalvageable. In such cases, cross-hand replantation may provide a viable reconstructive option, with the aim of restoring a single sensate and functional hand while avoiding the need for bilateral upper-extremity prostheses [1].

In asymmetrical bilateral injuries, when conventional orthotopic replantation may not be feasible, cross-hand replantation serves as a unique salvage technique by transferring the viable amputated hand to the contralateral forearm. Although the resulting limb is anatomically non-orthotopic, this procedure can provide useful prehensile function and improve functional independence in selected activities.

Case Presentation

A 26-year-old right-hand-dominant blue-collar worker presented to the emergency department following a railway wheel accident that resulted in devastating bilateral upper-limb injuries. On arrival, he was in hypovolemic shock and was resuscitated according to the Advanced Trauma Life Support (ATLS) protocol.

Clinical examination demonstrated markedly asymmetrical injuries to the upper limbs. The left upper limb sustained a severe crush amputation at the mid-humeral level with extensive soft-tissue destruction, segmental humeral bone loss, and irreparable injury to the axillary vessels, radial nerve, median nerve, and ulnar nerve. The right upper limb demonstrated a mangled hand with traumatic auto-amputation of all digits, including the thumb, extensive carpal destruction, avulsion of both flexor and extensor tendons, and

severe soft-tissue injury (Figures 1A-1D {D1-D3}). Radiographic evaluation confirmed the extent of osseous destruction.

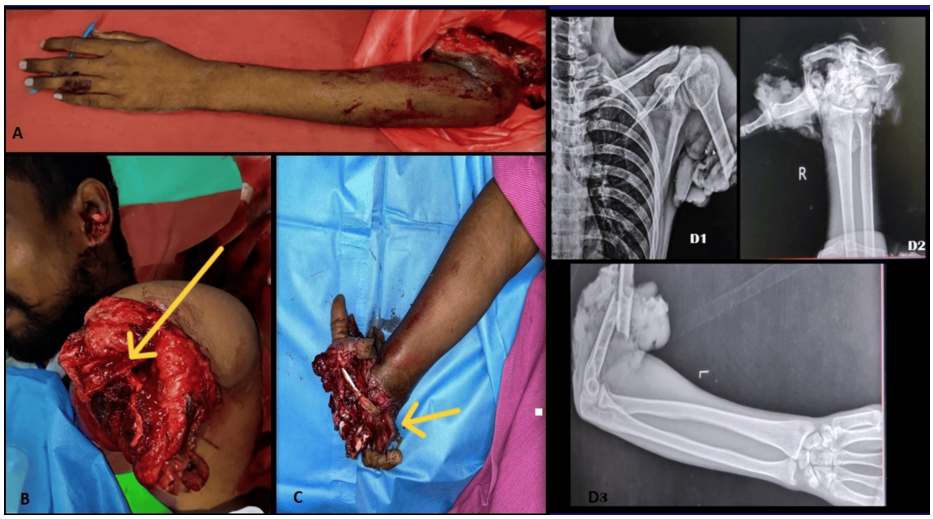


FIGURE 1: Bilateral upper-limb trauma - presurgical clinical and imaging findings.

(A) Amputated left upper limb. (B) Left upper-limb stump. Arrow indicating mid-humeral crush amputation with extensive neurovascular disruption. (C) Mangled right hand. Arrow indicating digital auto-amputation and carpal destruction, but a preserved viable forearm stump. (D1) X-ray of left upper-limb stump. (D2) X-ray of right forearm with wrist and hand (mangled hand). (D3) X-ray of left amputated stump.

Following hemodynamic stabilization, the patient underwent multidisciplinary evaluation. Orthotopic replantation was not feasible because of the extensive proximal neurovascular destruction of the left upper limb, and the right hand had non-reconstructable injury. However, the amputated left distal forearm and hand remained viable for replantation. After detailed assessment of the injury pattern and tissue viability, emergency cross-hand replantation of the amputated left hand to the right forearm was planned as the only reconstructive option capable of restoring meaningful upper-limb function.

Operative technique

Meticulous bench dissection of the amputated left distal forearm was performed. The radial and ulnar arteries, accompanying veins, median nerve, ulnar nerve, superficial branch of the radial nerve, and all identifiable flexor and extensor tendons were carefully isolated, tagged, and prepared for reconstruction (Figures 2A, 2B). We completed wrist disarticulation to facilitate transplantation.



FIGURE 2: Bench dissection of the amputated left upper limb.

(A) Flexor compartment tendons and nerves. (B) Extensor compartment tendons and nerves.

Palmar arch patency was checked using a Fogarty catheter. The dissected left wrist was replanted to the right wrist. Following internal fixation using 2-mm Kirschner wires (K-wires) (from the radius and ulna of the proximal right forearm through the carpals to the second and fourth metacarpals of the distal left hand), microvascular replantation was performed using a "criss-cross" arterial and venous anastomosis. The ulnar artery was larger than the radial artery, which led to difficulty in arterial anastomosis on both sides due to vessel diameter discrepancy. Venous anastomosis was completed. Median and ulnar nerves were coapted last. The skin flaps of the proximal right forearm and distal left hand were closed with intermittent sutures. Upon release of the tourniquet, robust digital perfusion was observed. Ischemia time was 9 h. Final clinical outcome is shown in Figures *3A*-*3C*. The surgical specifics are detailed in Table *1*.



FIGURE 3: Final clinical outcome of successful salvage.

(A) Volar aspect, (B) ulnar view, and (C) dorsal aspect.

Structure	Proximal right forearm	Distal left hand	Technique	Material
Bone	Radius	Fourth metacarpal	Through carpals	2 mm K-wire
	Ulna	Second metacarpal		
Tendons	FCU	FCR	Modified Kessler repair	3-0 polypropylene
	FCR	FCU		
	FDP	FDP	Epitenon continuous suture	5-0 polypropylene
	FDS (index finger)	FPL		
	ECRL, ECRB	ECRL, ECRB	Horizontal mattress	3-0 polypropylene
	EDC	EDC		
	EDM	EPL	Epitenon continuous suture	5-0 polypropylene
	EIP	EDM		
	ECU	APL, EPB		
Artery	Radial artery	Ulnar artery	End-to-end anastomosis	9-0 nylon
	Ulnar artery	Radial artery		
Vein	Cephalic vein	Basilic vein	End-to-end anastomosis	9-0 nylon
	Basilic vein	Cephalic vein		
	Dorsal vein	Dorsal vein		
Nerve	Median nerve	Median nerve	Epineural repair	7-0 polypropylene
	Ulnar nerve	Ulnar nerve		

TABLE 1: Complete structural reconstruction and fixation techniques.

FCR: flexor carpi radialis; FCU: flexor carpi ulnaris; FDP: flexor digitorum profundus; FDS: flexor digitorum superficialis; FPL: flexor pollicis longus; ECRL: extensor carpi radialis longus; ECRB: extensor carpi radialis brevis; EDC: extensor digitorum communis; EDM: extensor digiti minimi; EIP: extensor indicis proprius; ECU: extensor carpi ulnaris; EPL: extensor pollicis longus; APL: abductor pollicis longus; EPB: extensor pollicis brevis

Postoperative management and rehabilitation

The limb was immobilized in a below-elbow dorsal plaster splint, with the wrist maintained in neutral position, the metacarpophalangeal joints flexed to 60°, and the interphalangeal joints fully extended. Continuous intravenous heparin infusion was administered for the first five postoperative days (8 drops/min), followed by subcutaneous enoxaparin (0.6 mL once daily) for 10 days. Oral aspirin (150 mg once daily) was initiated on postoperative day seven as antiplatelet therapy and continued for three months. Regular microvascular surveillance was performed throughout the postoperative period to facilitate early detection of vascular compromise.

At two weeks following surgery, the patient was transitioned to a below-elbow dorsal blocking splint (Figure *4A*). A structured hand rehabilitation program was commenced under the supervision of a dedicated hand therapy team. Controlled active finger mobilization was initiated and progressively advanced to passive mobilization of all joints in a distal-to-proximal sequence while maintaining adequate protection of the repair. Skeletal stabilization was maintained until satisfactory clinical healing was achieved. Kirschner wires were removed at six weeks postoperatively, following which range-of-motion exercises were progressively intensified (Figures *4B*, *4C*).



FIGURE 4: Postoperative sequence of recovery.

(A) Patient in dorsal blocking POP, (B) ulnar view, and (C) volar view following K-wire removal.

POP: plaster of Paris

Functional recovery was assessed through the patient's ability to perform activities of daily living (ADLs) and instrumental activities of daily living (IADLs), which are summarized in Table *2*. Progressive improvement in functional independence was documented during follow-up, and representative functional outcomes are demonstrated in Video *1*.

ADLs/IADLs	No assistance	Some assistance	Complete assistance
Bathing	-	+	-
Dressing	-	+	-
Grooming	+	-	-
Oral care	+	-	-
Toileting	-	+	-
Walking	+	-	-
Climbing stairs	+	-	-
Eating	+	-	-
Using the phone	+	-	-

TABLE 2: Patient's ability to perform activities of daily living (ADLs) and instrumental activities of daily living (IADLs).



VIDEO 1: Video showing the patient's functional capabilities and ADL following cross hand replantation.

ADL: activities of daily living

View video here: https://youtu.be/koGY50vWtBc?si=iDBd6hou9KL67Mad

Results

Complete survival of the replanted hand was achieved without postoperative vascular compromise. There were no episodes of acute arterial insufficiency or venous congestion necessitating surgical re-exploration. The postoperative course was clinically uneventful. The patient tolerated the structured rehabilitation program, with progressive improvement in hand movement and functional use following the initiation of controlled mobilization. At follow-up, the replanted hand remained viable and demonstrated useful prehensile function. The patient was able to perform several activities of daily living independently, including grooming, oral care, eating, and phone use, although assistance was still required for selected activities such as bathing, dressing, and toileting.

Functional outcome

Functional recovery was assessed clinically based on hand use and the patient's ability to perform activities of daily living. The patient demonstrated useful prehensile function and progressive functional adaptation during rehabilitation. At the latest documented follow-up, the patient was independent in several activities, including grooming, oral care, eating, and phone use, while requiring some assistance with bathing, dressing, and toileting. Quantitative measurements of grip strength, pinch strength, total active motion, and two-point discrimination or Semmes-Weinstein monofilament testing were not systematically documented and therefore are not reported.

Discussion

The challenges posed by this novel reconstruction technique have limited its utilization to cases with bilateral traumatic upper-limb and lower-limb amputations in the literature. In 1982, Kutz et al. published a

case report of cross-hand replantation of the right hand onto the left forearm in the Journal of Microsurgery [2]. A study reported a subsequent nine-year follow-up. May Jr. et al. at Massachusetts General Hospital successfully performed elective free microvascular cross-hand transfer of the right hand to the left distal carpus in a 35-year-old photographer [3]. In 2003, Yildirim et al. from Istanbul performed trans-metacarpal cross-hand replantation [4]. In 2010, researchers in Istanbul reported crossover replantation at the arm level, and in 2013, researchers in the United Kingdom reported crossover replantation at the forearm level. In 1991, China reported trans-metacarpal replantation of the right hand onto the left [5]. In 2020, Sabapathy et al. performed a carpal-level cross-hand replantation in India [1].

Conclusions

Cross-hand replantation is a rare but feasible reconstructive option for selected patients with bilateral upper-limb amputation when orthotopic replantation cannot be performed. Our experience demonstrates that limb survival and useful functional recovery can be achieved in carefully selected patients with meticulous microsurgical technique and multidisciplinary postoperative care. As evidence remains limited to isolated case reports and small series, further accumulation of clinical experience with long-term functional assessment is necessary to establish the role of this procedure in contemporary upper-limb reconstruction.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Rasheedha Begum, Valarmathy V. Subramaniyan, Swetha Narayanan, Shonu Annet Kurian, Annapoorani Manoharan, Santhoshini Sivaramakrishnan, Rajeswari Balakrishnan

Acquisition, analysis, or interpretation of data: Rasheedha Begum, Valarmathy V. Subramaniyan, Swetha Narayanan, Shonu Annet Kurian, Annapoorani Manoharan, Santhoshini Sivaramakrishnan, Rajeswari Balakrishnan

Drafting of the manuscript: Rasheedha Begum, Valarmathy V. Subramaniyan, Swetha Narayanan, Shonu Annet Kurian, Annapoorani Manoharan, Santhoshini Sivaramakrishnan, Rajeswari Balakrishnan

Critical review of the manuscript for important intellectual content: Rasheedha Begum, Valarmathy V. Subramaniyan, Swetha Narayanan, Shonu Annet Kurian, Annapoorani Manoharan, Santhoshini Sivaramakrishnan, Rajeswari Balakrishnan

Supervision: Rasheedha Begum, Valarmathy V. Subramaniyan, Swetha Narayanan, Shonu Annet Kurian, Annapoorani Manoharan, Santhoshini Sivaramakrishnan, Rajeswari Balakrishnan

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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