

Assessment and management of amputations distal to the wrist

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Abstract

Hand amputation is a devastating injury which may result in permanent quality-of-life impairment. The goal of treatment is to anatomically restore the amputated limb in order to optimize sensation and range of motion of the injured structures. All cases should be emergently referred to a hand surgeon trained in microsurgery for assessment and management. Generally accepted indications for replantation include amputation at the level of the wrist or mid-palm, thumb or multiple digit amputation and single digit amputation when distal to flexor digitorum superficialis insertion. In addition, replantation should always be attempted for children. Appropriate primary care which includes wrapping the amputated part in saline-soaked gauze, sealing in a plastic bag, and immersing in an ice bath increases the viability of amputated tissue and facilitates replantation. This review explores hand amputation classification, indications for replantation, primary care of the amputated part, surgical replantation techniques, post-operative care, and complications following replantation surgery. Three cases, treated at the Halifax Infirmary, were identified to illustrate the clinical presentation and outcome of patients presenting with multiple digit, thumb, or mid-palm amputation.

Introduction

Hand amputation is a devastating injury with the potential for debilitating physical and psychological outcomes. The goal of treatment is to anatomically restore the amputated limb in order to optimize sensation and range of motion (ROM) of the injured structures.¹ Hand and digit amputation often occurs in the workplace (43%) and involves the use of industrial machinery.² Young males comprise the majority of hand amputation cases with a male-to-female patient ratio of 6:1. The average age at the time of injury is approximately 30 years.³

Replantation is a specialized microsurgical procedure which in North America is usually performed in tertiary care centres by hand surgeons trained in microsurgery.² The Halifax Infirmary, QEII Health Sciences Centre is a tertiary care facility receiving all patients requiring replantation surgery in the province of Nova Scotia. Three cases were identified from a prospectively maintained microsurgery database to illustrate the clinical presentation and outcome of patients presenting with (1) multiple digit, (2) thumb, and (3) mid-palm amputation. This review will enable a greater understanding of hand amputation classification, indications for replantation, and surgical replantation techniques.

Amputation Classification

An amputation injury may be classified according to the degree of amputation (complete versus incomplete), mechanism of injury (guillotine, laceration, crush, avulsion), level of transection, and age of the patient (child versus adult).⁴

The feasibility of replantation and rate of tissue survival varies according to characteristics of the injury and patient. Incomplete upper extremity amputations result in a higher incidence of successful reconstruction following replantation (92%) than complete transections (71%).⁵ Guillotine amputations are more amenable to reattachment than crush or avulsion injuries, as the zone of injury is limited to the amputation site and skeletal elements in the amputated extremity are in direct apposition to those at the reattachment site.⁶ A systematic review analyzing the success of digit replantation revealed that the level of injury does not influence the success of tissue survival with the exception of amputations of the distal phalanx which are two times less likely to survive replantation as compared to amputations at any other digit level.⁷ In addition, there is reduced survival of transplanted tissue in paediatric patients, however, tissue that does survive exhibits a greater degree of sensation and function compared with adults.⁸

Indications for Replantation

The generally accepted indications for replantation are listed in Table 1. Any amputation proximal to the metacarpophalangeal (MCP) joint should be assessed for possible replantation. Therefore, amputations at the level of the wrist and metacarpals are always indicated for replantation when the extremity is salvageable. Good or excellent recovery is reportedly obtained more often following replantation at the wrist (80%) than following transmetacarpal replantation (59%).⁹ Decisions regarding phalangeal replantation should be based on the realistic potential of the digit to contribute to function and not interfere with remaining hand function.⁴

Table 1. Indications for replantation following amputation distal to the wrist.

- Wrist or Mid-Palm Amputation
- Thumb Amputation
- Multiple Digit Amputation
- Single Digit Amputation Distal to FDS Insertion
- All Amputations in Children

Digital replantation should be attempted following amputation of the thumb or multiple digits. An “acceptable hand” is composed of three fingers of near normal length with near normal PIP joint motion, good sensation, and a functional thumb. The hand is deemed acceptable due to adequate function and aesthetics.¹ All digits should be considered for replantation in multiple digit amputation. Transposition of the best preserved digits onto the most intact stumps can however, successfully create an “acceptable hand” if all digits cannot be salvaged.¹⁰ Reconstruction of the thumb is essential as thumb amputation results in a 40 to 50% reduction in hand function. Excellent functional outcome is often achieved following thumb replantation as the majority of amputations leave the carpometacarpal (CMC) joint intact resulting in the preservation of the positioning mechanism for pinch and grasp independent of the mobility of the interphalangeal (IP) or MCP joints.¹¹

Single fingertip reattachment is indicated for amputations distal to the insertion of flexor digitorum superficialis (FDS) on the middle phalanx as they can have good functional and aesthetic outcome.¹² Patient satisfaction is much greater following successful fingertip replantation (100%) compared to direct skin closure (61%).¹³ Complete amputations at or distal to the DIP joint have a 78% survival rate following replantation with good overall digit function even with fusion of the DIP joint.^{14,15} In addition, replantation should always be attempted for children as they exhibit greater

ability to adapt to digit replantation, may have excellent functional outcomes, and are vulnerable to psychological stresses resulting from a physical deformity.¹²

Single digits at or proximal to the insertion of FDS are usually contraindicated for reattachment as replantation results in limited ROM at both the PIP and DIP joints thereby impairing overall hand function.¹⁶ Ray resection offers a more consistent functional outcome coupled with an acceptable aesthetic result.¹² Replantation should not be attempted for digits that have been severely mutilated, have multiple levels of injury, or have undergone prolonged ischaemia. Additional contraindications include life threatening injury and a lack of motivation to undergo a prolonged postoperative recovery.⁴ Smoking appears to have a profoundly negative effect on the survival of replanted digits as the replanted tissue of non-smokers survives at a rate of 11.8 times that of smokers.⁷

Care of Amputated Part

Ischaemia results in irreversible necrotic changes to muscle and soft tissue. The tolerance of skeletal muscle to warm ischaemia is six to eight hours, however, a digit may remain viable for up to twelve hours due to the absence of muscle tissue.¹⁷ Successful replantation has been reported beyond 24 hours with appropriate care (Table 2). All amputated parts should be wrapped in saline-soaked gauze, sealed in a plastic bag and immersed in an ice bath.^{12,18} It is important to avoid directly exposing the amputated part to ice to prevent freezing the tissue. Digital replantation surgery is considered an emergency procedure and is commenced as soon as possible to lessen the risk of tissue loss.

Case 1: Multiple Digit Amputation

A 48-year-old right-hand-dominant male sustained lacerations to his right hand while working on a lawnmower. Examination in the emergency department revealed that there was complete amputation of the index finger at the proximal interphalangeal (PIP) joint, complete amputation of the middle finger through the middle phalanx and near amputation of the ring finger at the distal interphalangeal (DIP) joint (Figure 2). The operative plan was to replant the right index and middle fingers with reconstruction of the ring finger. Following exploration, the plan was amended to replantation of the index finger, revision of the middle finger with local flaps, and reconstruction of the incompletely amputated ring finger. Two weeks following surgery this patient’s ring finger and “significantly shortened” middle finger were healing well (i.e., pink with normal peripheral

pulses); however, venous congestion was noted in the index finger. He was admitted for hourly finger poking and prescribed penicillin, cloxacillin, and heparin (IV and soaks). Leeches were not employed because the risk of infection was considered too great. Seven months following injury all replanted digits demonstrated good healing. He achieved flexion at all DIP and PIP joints enabling him to make a full fist.



Figure 2. Multiple digit amputation.

Surgical Technique

In replantation surgery, the initial task is to identify all nerves, arteries, veins and tendons in both the amputated part and the stump. The wound is prepared by removing all nonviable tissue and comminuted bone fragments. To expose and retrieve retracted flexor tendons, a carpal tunnel release may be needed using a Brunner zigzag incision along the volar surface of the wrist followed by longitudinal incision of the deep transverse carpal ligament. Sequence of tissue repair varies among surgeons,¹² however, a typical operative sequence is: (1) debridement, tissue identification, and tagging, (2) bone shortening and fixation, (3) flexor and extensor tendon repairs, (4) nerve repairs, (5) arterial anastomosis, and (6) vein anastomosis concluding with (7) skin and soft tissue closure.

Bony Fixation

The bone ends are resected 0.5 to 1.0 cm with an oscillating saw to allow good approximation of the nerves and blood vessels. Bony fixation of digits is often accomplished with the use of 0.035 inch Kirshner wires (K-wires). Techniques suitable for bone fixation include intramedullary K-wires, crossed K-wires, and K-wires in combination with intraosseous circlage wires.¹⁹ Metacarpal fractures may be reconstructed using a titanium plate and screws fixated to the dorsal aspect of the metacarpals.

Tendon Repair

Tendon repair is achieved using the surgeon's preferred technique, often a modified Kessler core-type suture repair (Figure 1a). The suture material must be strong and of relatively small calibre. Generally, the suture employed is 3-0 or 4-0 calibre in either a braided or monofilament design. Core sutures are reinforced with a continuous epitendinous suture using 6-0 nylon (Figure 1b).²⁰ Increasing the number of strands across a repair site improves the strength of the repair without resulting in more adhesions.²¹ However, knots within or in close proximity to the repair site increase the risk of adhesion formation.²⁰

Nerve Repair

A nerve is composed of groups of fascicles (axon bundles surrounded by perineurium). Prior to reapproximation, the nerve should be trimmed until a normal fascicular pattern is observed in both stump and amputated tissue.²⁰ Epineurium, connective tissue surrounding a nerve, is sutured together end-to-end with 8-0 nylon suture in interrupted fashion. Generally, digital nerves require two to three epineurial sutures.¹²

Table 2. Primary care following amputation injury.

- | | |
|----|--|
| 1. | Examine amputation site and part (avoid probing with instrument) |
| 2. | X-ray stump and part |
| 3. | Wrap part in saline-soaked gauze |
| 4. | Seal in plastic bag |
| 5. | Immerse in ice |
| 6. | Immediately contact plastic surgeon |

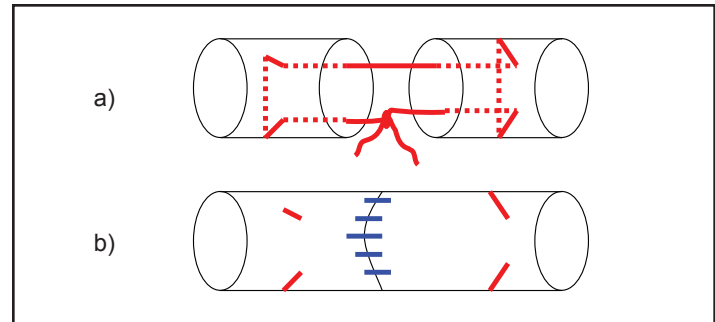


Figure 1. a) Modified Kessler core-type suture repair, and b) continuous epitendinous suture (blue).

Case 2: Thumb Amputation

A 55-year-old right-hand-dominant construction worker presented to hospital following complete amputation of his left thumb at the base of the proximal phalanx with a skill saw. The laceration was ragged and there was a longitudinal split in the amputated thumb (Figure 3a). Microsurgery was performed to replant the amputated digit. The IP joint was fused since the saw injury destroyed the joint, however, his resulting pinch and grip strength were normal. Eight months after injury the patient had normal flexion and extension at the MCP joint and was able to oppose the thumb with all fingers (Figure 3b).

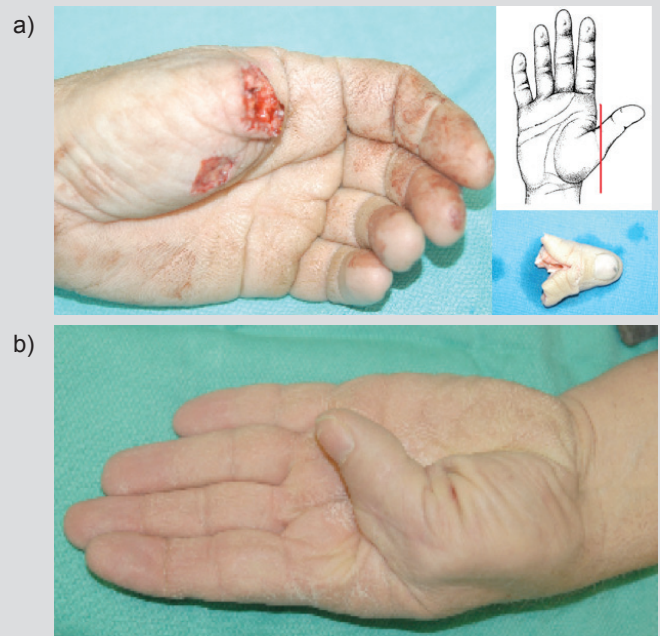


Figure 3. a) Thumb amputation, and b) functional outcome eight months following thumb replantation.

Case 3: Mid-Palm Amputation

A 26-year-old left-hand-dominant fisherman suffered a guillotine injury to his right hand while using a hydraulic fish bait cutter. He was airlifted to Halifax where it was determined that he had complete amputation of his thumb through the interphalangeal (IP) joint and complete amputation of the index, middle, ring and little fingers through the distal metacarpals with one flexor tendon remaining attached to the amputated middle finger (Figure 4a). Amputated digits were replanted in a seventeen-hour surgery which restored his thumb at the level of the IP joint and index, middle, ring and little fingers following transection through the metacarpals. His recovery was complicated by full thickness skin loss on the dorsal aspect of his hand, an 8 x 4 cm necrotic skin flap overlying the area of venous anastomoses during replantation surgery. A split thickness skin graft was taken from the left anterior thigh and placed at the site of full thickness loss following debridement of the necrotic tissue. The patient underwent further surgeries for first web space scar release and extensor tenolysis. Seven years following injury, the patient has a strong grip and can form a fist (Figure 4b). He can oppose his thumb to the second, third and fourth fingers, however, there is scissoring of the small finger. He was offered an MCP arthroplasty to restore joint mobility following significant osteoarthritic changes to the MCP joint of his index, middle, ring and little fingers, however, he would like to avoid further surgery at this time. Currently, he is functioning well on his fishing vessel.

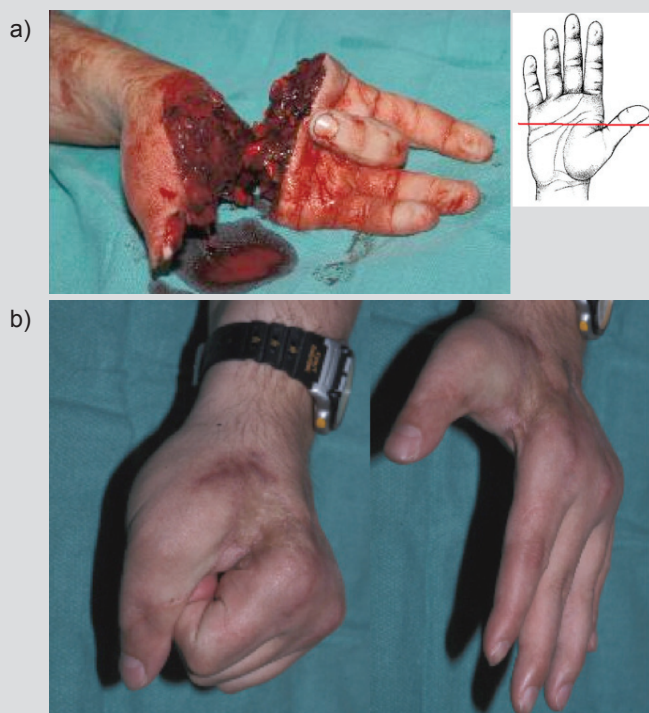


Figure 4. a) Mid-palm amputation, and b) functional outcome seven years following replantation surgery.

Vascular Repair

Using the operating microscope, arteries and dorsal veins are repaired with 9-0 or 10-0 nylon suture in interrupted fashion. Arterial anastomoses should be performed by approximating normal intima that is not under tension. Tension may be relieved by further bone shortening or the use of a vein graft.¹⁸ Digit survival may be enhanced by the repair of both digital arteries in each finger as small lumen diameter (less than 1 mm) makes these vessels prone to thromboses.¹² Venous anastomosis is similar to arterial anastomosis, however, veins are often collapsed and, as a result, difficult to locate.^{12,18}

Post-Operative Care and Complications

Following surgery patients should be kept warm and well hydrated to decrease the risk of peripheral vasospasm.⁴ Patients may be given acetylsalicylic acid, low dose heparin or dextran 40 postoperatively to reduce the risk of vascular thrombosis; however, no consensus exists regarding use of anticoagulants following replantation surgery.²² Following one to two weeks of immobilization an aggressive ROM exercise program is initiated in consultation with occupational therapy.⁴

The most significant perioperative complications include arterial and venous insufficiency, which left untreated will lead to loss of the replantation. Arterial occlusion may be due to external compression or internal obstruction. Arterial thrombosis manifests as a cool, white, pulseless digit. It is treated with re-exploration and revision of the arterial anastomoses. Patients with venous congestion present with a cyanotic, turgid digit demonstrating brisk capillary refill.⁴ Medicinal leeches may be used to relieve congestion since hirudin, an anticoagulant secreted by the leeches, improves blood flow and encourages oozing of blood from the application site.¹⁸ Alternatively, the fingernail can be removed and the nail bed lacerated to promote bleeding.

Late complications include cold intolerance, poor tactile sensation resulting from inadequate nerve regeneration, sympathetically maintained pain syndrome, and stiffness secondary to tendon adhesion. Adhesions may be relieved by tenolysis, however, this procedure carries the substantial risk of devascularizing replanted digits and should only be performed in severe cases.¹² In addition, first web space contracture is common following hand trauma and may occur even in the absence of injury to the body of the hand. Progressive contracture of the muscle fascia, skin and ligaments cause thumb adduction thereby impairing grasp ability. Contracture following digit amputation may be treated by splinting of the adducted thumb or surgical intervention.¹

Note

Cases presented in this review represent excellent functional outcome following replantation surgery. Not all amputation injuries are amenable to replantation and not all patients who undergo replantation surgery will experience an equally satisfactory functional outcome.

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