

Finger Replantation Injury: Approach to Diagnosis and Treatment in the Emergency Department

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ABSTRACT

BACKGROUND

Finger amputation is the separation of finger parts mostly due to trauma. It is a common case in emergency department particularly in the developing countries where various accidents occur at workplace. The finger makes up for the high functionality of the hand, and care of these cases is often complicated. Replantation is a surgical procedure to reattach amputated parts which aims to restore both the functionality and form of amputated limb. Its procedure involves a sequence of repair including bone fixation, repair of tendon, muscles, and microsurgical repair of the artery and veins. Health care providers in the emergency department must recognize amputation injuries in a timely manner so as to prepare for prompt replantation if indicated. There are different classification systems that can be used to describe the replantation injury. Thorough evaluation and diagnosis of finger amputations must be communicated well with the referring specialist, as many issues must be considered including level and type of injury, tissue viability with regard to ischemia time, as well as patient's comorbidities. Indications of replantation can be absolute or relative, and must be discussed with both replantation team and the patient. Preservation of the amputated part is important as it is a key prognostic factor of replantation success. Patient must be educated well about the risks and benefits of replantation, as well as the need for rehabilitation strategy and close monitoring in the future to prevent long-term complications of the replanted finger.

KEYWORDS

Finger, Replantation Injury, Diagnosis, Treatment

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INTRODUCTION

Replantation is defined as the reattachment of a completely amputated limb or body part which entails restoring both the neurovascular and musculoskeletal structures.^{1,2} Revascularization, on the other hand, is the reattachment of an incompletely amputated or detached limb, irrespective of the amount of tissue holding it.³ Partial digit and fingertip amputation are the most common presentation, followed by complete digit and multiple digit amputation.⁴ Traumatic hand and finger amputations constitute 12% of all trauma cases in United States, causing high morbidity and long-term disability.⁵ A 10-year retrospective study in France discovered that upper limb amputation was a main surgical emergency with incidence of 2% of the population.⁵ The incidence is found to be higher in male adults than women with a ratio of 4:1 with cause of injury involving work with power tools.⁴ Other common mechanism of trauma include motor vehicle collision, industrial, agricultural, as well as household accidents.⁶ While the number of cases have gradually fall in developed countries, however this is not the case in developing countries where there tends to be lack of health and safety regulation at workplace.⁷ Therefore it is of significant importance that these cases are diagnosed and treated in a timely manner at the emergency department, with proper preparation for the following replantation surgery.

REVIEW OF LITERATURE

Any amputated part of the body may be described according to different classifications involving the anatomical level, completeness of amputation, and its spectrum of injury.⁸ These will help in determining the surgical techniques deemed appropriate.

Anatomical Level

Amputations of the upper limb can be classified as being proximal or distal to the radiocarpal joint.³ Amputations proximal to the radiocarpal joint or known as major limb replantation, are generally more severe.^{1,3} Due to the increased muscle mass proximally, there is a shorter period of ischemia that can be sustained and thus posing a higher risk of myoglobinuria.⁹ This type of amputation will not be further discussed in this review. When describing hand amputations particularly of the fingers which are distal to the radiocarpal joint, the flexor tendon zones of injury are main points of the functional anatomy.¹ These zones of flexor tendon refer to the insertion of flexor digitorum profundus, ligaments of the digits as well as the carpal tunnel site.³ Amputations of the finger can be categorized according to numerous classification systems coined by Tamai, Allen, Foucher et al, Ishikawa et al, and Hirase.^{3,10} (Figure 1)

Each zone described by the different classification systems carry its own anatomic characteristics and impact in surgical outcomes. In Tamai's classification, zone 1 injury

entails digital pulp up to base of nail, while zone 2 injury involves nail base up to the distal interphalangeal joint.¹¹ Another classification system by Yamano added a further zone 3 injury which comprises the distal interphalangeal joint up to the metacarpophalangeal joint.^{11,12} Furthermore, Ishikawa made subdivisions out of Tamai's classification, clarifying the presence of four subzones. The Hirase classification, on the other hand, classifies three zones of injury with zone 2 further divided into zone 2A and 2B. The digital artery termination is emphasized in this system, where zone I is the most distal zone with almost no chance to suture arterial and venous vessels, and zone 2A and 2B extends to the distal end of distal and proximal arteries respectively.¹³ Similarly, Allen's classification comprise of zone 1 to zone 3 which corresponds to the distal to lunula area seen in Tamai's zone 1. Zone 4 of Allen's classification entails the distal to distal interphalangeal joint area as depicted in Tamai's zone II.¹⁴

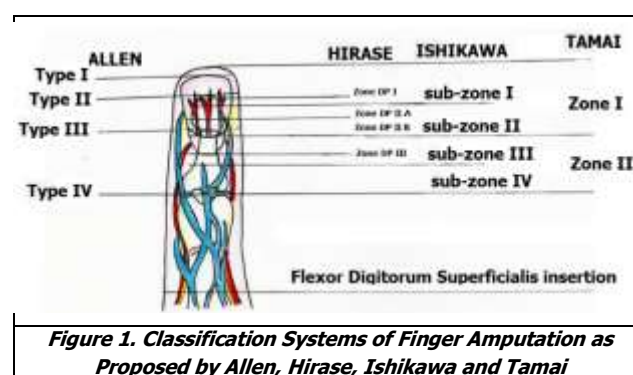


Figure 1. Classification Systems of Finger Amputation as Proposed by Allen, Hirase, Ishikawa and Tamai

These classification systems help predict the risk and outcome of surgery.³ Finger amputations that are more proximal require more complex and prolonged rehabilitation due to the need of nerve regeneration.⁷ On the other hand, amputations that are more distal pose a bigger challenge for microsurgical repair, while rehabilitation may be less complex and needed in a shorter period.⁷ Fingertip amputation at Tamai's Zone 1 was traditionally regarded as a non-replantable amputation, although other studies showed ability for reconstructive option.¹⁵ This difficulty is mainly due to the small-size artery and lack of dorsal vein.¹⁵

Completeness of Amputation

Traumatic amputations must also be classified as both complete or total amputation and incomplete or subtotal amputation. In complete finger amputation, no connecting tissue is present which necessitate a replantation.^{1,3} This is not the case in incomplete amputation, where although most functional structures have separated, however a soft tissue connection less than one-quarter of the circumference is still present.¹⁶ An incomplete finger amputation requires revascularization which is known to be of higher difficulty than replantation.¹ Apart from being commonly associated with revascularisation, the definition of incomplete amputation also means there is evidence of a residual circulation needing a vessel anastomosis.¹⁶ The use of vein

grafts, nerve grafts or skin flaps may be needed to repair its structure.^{3,16}

Spectrum of Injury

Mechanism of injury is helpful to assess severity and extent of finger amputation. A classification proposed by Yamano observed the nature of injury as a causative factor in success of replantation. He described three types of injury namely Guillotine, crush, and crush avulsion injury.¹⁷ A Guillotine injury is due to objects with narrow sharp edges such as knives. It results in a clean cut amputation with minimal debridement necessary.^{1,17} A crush injury is due to objects with broad and blunt edges such as saw or wooden log.¹⁸ It may create a moderate to severe crushed amputation with significant tissue loss from proximal to distal end of the amputation, requiring an extensive debridement.¹⁸ The third type is the crush avulsion injury which entails a severe crush injury that may or may not be combined with an avulsion.^{16,18} A study reported that crush injury is a relative contraindication of replantation although it can be a success in some cases.¹⁹ An avulsion itself is caused by traction force such as machine press or door, resulting in loss of tissues at different levels according to the tensile strength caused.²⁰ A specific type of avulsion is the degloving injury where soft tissue envelope is pulled off while the remaining bone and tendinous apparatus are preserved.²⁰ A "ribbon" sign or a "red-line" sign seen at the finger amputation marks a severe avulsion injury to the neurovascular bundles.²¹ These indicate a poor prognosis for replantation due to intimal tears of digital vessels and severe traction and torsion of the vessels.²²

Initial Assessment

A replantation injury must be assessed according to the standard trauma care as proposed by the Advanced Trauma Life Support (ATLS) protocol.¹⁸ A pertinent history taking is crucial in deciding whether or not replantation can be successfully done. In regard to the injury, a detailed history of mechanism of injury, duration of ischemia time, and presence of coexisting injuries.¹⁸ Establishing ischemia time is important as digits can be replanted if within 24 hours of cold ischemia and 12 hours of warm ischemia time.²³ Although finger amputations are not always associated with coexisting injuries, however other life-threatening injuries must not be overlooked.²⁴ Age of the patient can determine need of replantation. The elderly would less opt for sophisticated hand function and cosmesis appearance than the younger and more productive patients which more likely to expect high return of function.^{2,23} Contrary to this, any amputation at any level or mechanism in children must be proceeded with replantation.²² Children are indicated to undergo replantation due to high recuperative ability that results in better functional outcome.²² Additionally, patient's comorbidities such as diabetes, vascular diseases, and history of smoking must also be known as part of preoperative evaluation.¹⁸ A study reported that smoking and caffeine consumption cause a poor microvascular patency, with nonsmokers showing 11.8 times higher

replant survival rate.²⁵ Absolute contraindications of replantation such as recent history of myocardial infarction or dementia must be asked beforehand. Other patient's social history includes occupation and social status which may determine patient's expectation and need of replantation for work or other social needs.¹⁸

Management in the Emergency Department

If patient received prehospital care before arrival to the emergency room, ATLS principles must be followed by simultaneously stabilizing and resuscitating patient with warm intravenous fluids to prevent proximal vessel spasm.²⁶ A foley catheter is placed to monitor fluid resuscitation although may not always be required in single digit replantation. It is important to note that the idiom "life over limb" remains priority in traumatic amputation cases.²⁷ Both the patient and the amputated part must be cared for in a timely manner. Any finger amputation causes haemorrhage that must first be controlled by applying non-adherent pressure dressing and elevating the patient's arm.¹⁸ If it is feasible, prehospital team should document the stump and the amputated digit before dressings are applied so as to efficiently notify the emergency department team without needing to repeatedly remove the pressure dressing.¹⁸

Based on the estimated blood loss and hemodynamic status of the patient, cross matched blood must be prepared while ongoing gross evaluation of the amputated part ensues.⁸ It is advised that the amputated part is matched with the proximal finger stump, ensuring that the soft tissue defect does not create a large gap which will hinder a successful replantation.¹⁵ As part of the evaluation and after patient is stabilized, an x-ray of the finger can be taken to confirm anatomical level of the amputation as well as presence of any bone defects.¹⁵ Radiograph also helps to assess the degree of comminution and involvement of intra-articular defects.⁸ If available, a closer evaluation of the blood vessels can be done by use of microscope or loupe magnification.⁸ This can reveal specific signs such as "ribbon" sign or "red-line" sign which signify poor outcome of replantation.²⁸

As for the amputated finger, proper preservation method must be followed through as it plays a prognostic role for digit survival.¹⁹ Initially the amputated part should be cleansed with normal saline irrigation until any foreign material has been removed.¹⁹ Afterwards the amputated part should be immediately immersed in a saline solution or alternatively wrapped in a sheet of gauze that has been moistened with saline solution.^{1,18} Afterwards it should be placed in a clean sealed plastic bag which will then be submerged in an ice water solution preferably at of 4°C.^{8,18,28} (Figure 2) The plastic bag does not necessarily have to be sealed tightly.²⁴ However the temperature of the ice water must be precisely followed, as placing the amputated finger directly in contact with ice below 0°C temperature can cause frostbite injury of the vessels and should be avoided instead.²⁹ Meanwhile the proximal amputation site can be wrapped with gauze soaked in lidocaine as a means to reduce pain.¹⁵

It is important to note that fragment of the amputated finger must not be discarded, since these can be valuable for future reconstruction if required.⁸ These fragments can be source of nerve, tendon or skin tissues.³⁰ Haemorrhage control can be done by continuous clean compressive dressing, but blind ligation or clamping of vessels should be avoided as it can cause further injury to blood vessels or nerves.^{1,3} If available a proximal tourniquet can be applied and after the bleeder is well-identified, clamping or ligation can be carefully done.⁸ Tetanus prophylaxis should be administered if indicated, and broad spectrum antibiotics is given.¹⁸ The choice of prophylactic antibiotic for traumatic amputation is first-generation cephalosporin, whilst for extensively contaminated injuries an aminoglycoside with a third-generation cephalosporin may be effective.¹ A study has also reported use of regional nerve block preoperatively as pain relief, blockage of sympathetic activation and vasodilation.²⁶

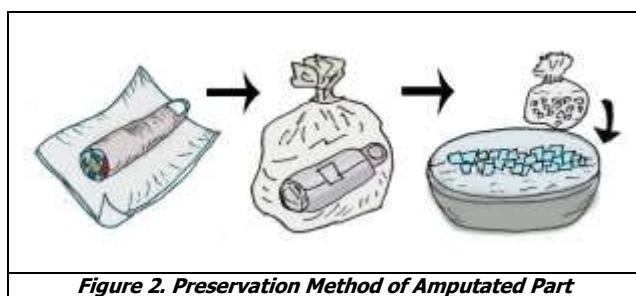


Figure 2. Preservation Method of Amputated Part

Indications for Replantation

Patients must be well informed that not all amputations can be replanted and that there are several other treatment options suitable such as shortening of the stump, transplant of digit, or pollicisation of index finger for thumb amputations.^{18,20} Both the surgeon and patient must discuss about the post-operative care which involves long-term rehabilitation program, expected functionality gain, and even possible secondary procedures in the future.⁸ In regard to the factors of injury, a common absolute indication of replantation is amputation of the thumb. A study reported that the thumb represents up to 50% of hand function, and thus a loss of thumb must be replanted.³¹ A thumb that is able to grasp although remains stiff is still of significant value for hand functionality.¹⁸ Multiple digit amputations, and amputations at or proximal to the palmar site are also strong indication for replantation.²⁶

Indications	Contraindications
The thumb	Concomitant life-threatening injury
All amputations in children	Multiple segmental injuries in the amputated part
Multiple digits	Extremely severe crush or avulsion
The palm wrist, and distal forearm levels	Extremely contamination, as in some farm injuries
	Prior surgery or injury to the extremity that precludes replantation
	Precluding systemic illness
	Extremely prolonged warm ischemia
	Physical problem

Table 1. Indications and Contraindications of Finger Replantation

Regarding age of the patient, paediatric patients at any level of amputation must also be replanted due to their high

potential for nerve regeneration, sensory self-re-education, and better healing capacity.^{26,32} Relative indications of replantation include single digit amputation through zone 2 level distal to flexor digitorum superficialis tendon.¹⁸ It also includes severe crush injuries, heavily contaminated amputations, or that which underwent prolonged ischemia.²⁶ Advanced age is not a mere contraindication for replantation, as long as the patient is medically suitable and healthy to undergo surgery.²⁶ Contraindications of replantation involve presence of concomitant life-threatening injuries, extremely severe crush injury, and any precluding illness.³⁰ (Table 1)

Replantation Procedure

The technique of replantation is generally up to the surgeon's preference. However most surgeons advocate a sequence of repair in the order that is performed.²⁸ The first repair is bone fixation with or without bone shortening which depends on the case.²⁰ Bone fixation uses K-wires, internal fixation, screws and plates.²⁸ The bone may be shortened up to 10 mm to provide bone apposition when comminuted fractures or vital structures are avulsed in the injury.²² The second part of the sequence is repair of extensor and flexor tendons.⁸ After tendon repair, an inflated tourniquet is used to accommodate nerve repair.⁸ If primary nerve repair is not possible, other techniques using nerve allograft or nerve autograft can be used.²⁸ Afterwards an arterial anastomosis with microscope is conducted by ensuring that damaged vessels are first excised to enable anastomosis.²⁸ The vessel may be immersed in papaverine to promote vasodilation.¹⁰ If suitable veins are present, it is suggested that 2 veins are repaired for every 1 arterial repair, in which vein grafts may be needed in some cases.^{28,33}

Complications of Replantation

Potential complications of replantation may manifest as both early and late complications. Common early complications include arterial or venous insufficiency and post-operative infection which may be evident in as early as two days.^{18,34} To prevent this, vasoconstriction must be avoided by keeping patient warm, hydrated and pain-free.¹² A close observation of the replanted finger must be done to note any changes in skin colour, turgor, or capillary refill time.⁸ A cool, pale and pulseless finger indicates an arterial thrombosis and prompt referral for surgical exploration must be done.¹⁵ Late complications may present as intolerance to cold which commonly regress after two years, adhesion of tendon, and malunion of the bone particularly in children.⁸ In severe case of tendon adhesion, a tenolysis can be performed while still considering the risk of a devascularised replanted digit.⁸

CONCLUSIONS

Finger replantation injury is a common presentation in emergency department. It is crucial that all health providers recognize the appropriate management by performing

timely diagnosis, and treating both the patient and amputated part comprehensively. A careful assessment during history taking and physical examination must be able to classify the injury according to the level of anatomy, completeness of injury, and mechanism of injury itself. Along with resuscitation of the patient, care must be taken to preserve the amputated part following appropriate techniques to prevent frostbite and non-viability of the part. It must be ensured that patient has fulfilled indications of replantation, and furthermore well informed about the management plan. Although replantation has been known to show good functional outcome, patient must still be well aware on the possible postoperative complications.

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