Amputations of the Fingers and Hand: Indications for Replantation

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Abstract

With hand and digital replantation now widely available in most urban settings, initial treating physicians must be aware of the factors that may influence outcome, so that informed decisions can be made regarding referral for replantation and appropriate early treatment. The author outlines the factors pertaining to amputations of the fingers and hand, provides general guidelines for indications for and contraindications to replantation, and discusses reported results.

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The achievements of modern microsurgery were heralded by the first arm replantation by Malt in 1962,[1] followed by the first digital replantation by Komatsu and Tamai in 1965.[2] With the advent of refined microscopes, sutures, and needles, along with specialized surgical training, replantation has become a routine part of hand-surgery practice in centers all over the world.

While replantation is by no means a simple endeavor or one to be undertaken lightly, the facility with which amputated parts can be successfully replanted is attested to by viability rates that now approach 90%.[3-7] As a result, it is no longer sufficient to have merely replanted the part successfully; rather, and perhaps more important, the function of the injured hand should be an improvement compared with the alternative of revision amputation, with or without use of a prosthesis.

Clearly, survival does not equate with function. Amputations constitute multisystem injury, with disruption of skeletal support (bone), motor function (muscle), sensibility (nerve), circulation (blood vessel), and soft-tissue coverage (skin).[8] These areas must all be carefully and individually addressed if a satisfactory outcome is to be obtained.

The initial patient management and the complex factors that relate to the decision-making process after amputation are critical to those physicians outside hand centers who initially encounter the patients. Knowledge of the accepted outcomes is important to every practicing surgeon so as to be better able to counsel patients.

Care of the Amputated Part

The amputated part should be wrapped in gauze moistened with saline or lactated Ringer's solution and placed inside a plastic bag or sterile container. The bag or container should then be placed in a larger receptacle containing ice, thereby avoiding direct contact of the amputated part with ice, which may result in frostbite. Dry ice should never be used, as permanent tissue damage will ensue.

Variables Affecting Outcome

A number of factors have a bearing on the decision-making process after amputation, among them the site and nature of the injury, the duration of ischemia, the presence of contamination, and various patient characteristics.[6,9,10]

Injury-Site Factors

The location and number of amputated digits, the level and type of injury, the degree of ischemia, and the local environment in which the injury occurred are all factors that must be considered. With respect to digit location, the thumb assumes prime importance in hand function and should be replanted if at all possible. Replanted border digits (index and small) often do not contribute greatly to function, as the index fin-

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ger is often bypassed by the long finger, and lack of full small-finger motion may result in decreased grip strength.

Digit Number

A solitary digit is less likely to be restored sufficiently to improve hand function (excluding the thumb) and is often not a candidate for replantation. However, as the loss of multiple digits may considerably compromise hand function, an attempt should be made to replant the least damaged digits into the most functional positions, preferably resulting in a thumb opposing two digits to provide prehension.[5]

Level of Injury

Determination of the level of injury is also important. Amputations in zone II (proximal to the insertion of the flexor digitorum superficialis [FDS]) have a much poorer prognosis, primarily due to limited proximal interphalangeal (PIP) joint motion; replantation is generally not appropriate in this setting.[4] Distal replantations are usually more straightforward surgically and result in better sensibility. More proximal amputations at the metacarpal or wrist level are associated with devastating loss of hand function; replantation often yields surprisingly good results.[8]

Type of Injury

Sharp, guillotine amputations are ideal candidates for replantation. Crush and avulsion injuries are associated with varying degrees of soft-tissue damage, jeopardizing both viability and functional return. Two signs are helpful in demonstrating arterial injury after avulsion (Fig. 1). The first is the red-line sign,[11] a red streak along the lateral border of the digit, which results from hemorrhage from torn vascular branches along the course of the digital artery after a traction injury. The second is the ribbon sign,[12] which refers to the coiling or twisting of the artery due to disruption of the vessel wall layers after traction and recoil. For replantation to be successful in these instances, the zone of injury must be bypassed with vein grafts.[13] Segmental or multilevel injury to the part usually precludes a successful outcome in terms of both viability and function.

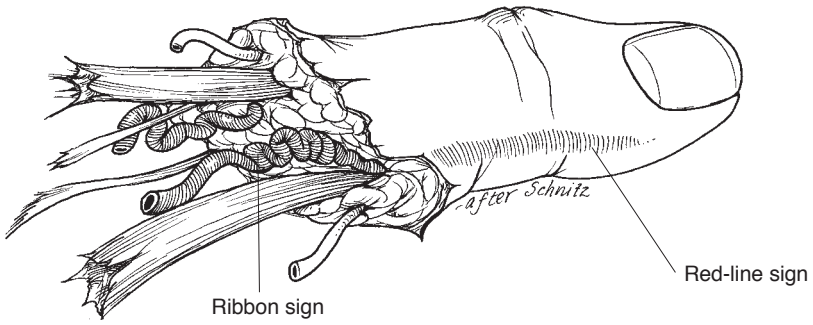

Fig. 1 The red-line and ribbon signs.

Duration of Ischemia

The degree of ischemia can also have an effect on outcome, depending on the level of injury and the amount of vulnerable muscle tissue present. Warm ischemia time should generally not exceed 12 hours for digits and 6 hours for amputated parts with substantial amounts of muscle (i.e., proximal to the wrist).[6] Cooling to 4°C to 10°C extends the ischemia time to 24 hours or more for digits and 10 to 12 hours for major limb replants.

Contamination

The local environment should be examined, as injuries associated with major contamination (e.g., farm and barnyard injuries) are prone to serious infection and consequent failure, as well as potential systemic sequelae.

Patient Age

The viability rates are slightly lower in the very young due to the increased technical difficulty in anastomosing smaller vessels, the larger proportion of crush and avulsion injuries compared with adults, and the more aggressive stance toward replantation, with an attempt to replant as much as possible in children. Furthermore, anxiety and pain produce increased vasospasm in the pediatric population.[14]

The vessels in very old patients may be affected by arteriosclerosis, which would compromise repair. Also, elderly patients are often a higher anesthetic risk and may not be interested in pursuing a lengthy rehabilitative process, depending on their current lifestyle.

Associated Injuries

The presence of serious proximal limb trauma may preclude a satisfactory overall result despite a successful distal replantation. Moreover, concomitant life-threatening injuries take priority over replantation and should not be overlooked during the initial patient evaluation.

Preexisting Impairment

Prior trauma or dysfunction due to disease (e.g., severe arthritis) of

the involved part may militate against replantation if reasonable function is doubtful. Similarly, the presence of a significant past medical history—particularly cardiac disease, poorly controlled diabetes, other systemic disease, peripheral vascular disease, hypercoagulopathy, serious psychiatric illness, or otherwise high anesthetic risk—may adversely affect the outcome of replantation efforts.[9,10]

Social Factors

The patient's vocation (e.g., a pianist), avocation, motivation, compliance (not only desire but also ability to comply), and history of smoking or drug or alcohol abuse can all influence outcome. Cosmesis is also an important consideration for some individuals, sometimes overriding concerns about function and providing the primary impetus for replantation.

Expenditure of limited healthcare resources for replantation is a complex financial and moral issue relating to patients, insurance carriers, and society as a whole. The increased cost of replantation surgery must be weighed against the potential functional improvements and enhanced future use of the hand. In addition, substantial wages are lost because of time off work during the lengthy rehabilitative period after replantation, especially if reconstructive procedures are required. Job security may be endangered as well.

Beliefs in some ethnic groups (e.g., in some Asian cultures) may cause those who have lost a body part to experience severe social stigmatization, such that restoration of body integrity overrides concerns about function. The same may be true for individuals who request replacement of a lost part because of their religious beliefs.

Risks of Surgery

The risks of operative intervention for replantation include the standard risks of surgery as well as the risks unique to replantation, including complications due to prolonged anesthesia, hemorrhage, transfusion, compartment syndrome, metabolic disturbances, and infection.[15]

Anesthesia is generally provided by regional blocks to enhance vasodilation from sympathetic blockade. General anesthesia may be used as an adjunct, particularly for long procedures. Hemorrhage begins at the moment of amputation and continues during the revascularization process. Blood loss may be substantial but is often overlooked because of the slow rate over a lengthy period of time. Hemorrhage is exacerbated by the intraoperative use of agents to avoid thrombosis, such as heparin and dextran. Postoperatively, leeches may be used in cases of venous congestion, resulting in further blood loss. Transfusion risks include transfusion reaction, coagulopathy, and transmission of disease, such as hepatitis and human immunodeficiency virus infection.

Compartment syndrome is seen predominantly with major limb replantation when a substantial amount of muscle is involved and warm ischemia time exceeds 6 hours. This complication can threaten the viability of the replant as well as the patient.

Metabolic disturbances are seen with major limb amputation involving muscle, as toxic by-products of metabolism accumulate and are released into the circulation after vascular anastomosis, with resultant acidosis, hyperkalemia, and myoglobinuria. Infection is always a risk after open injury, especially in contaminated wounds. Infection may also be a consequence of inadequate debridement of necrotic tissue, especially muscle tissue in major limb amputations.

Indications

The unique functional role of the thumb in opposition and pinch dictates that it be replanted whenever possible. Similarly, the considerable decline in hand function that follows loss of multiple digits may be ameliorated by restoring the least damaged fingers to the most functional positions based on the degree of recipient-site injury and the ability to obtain basic pinch function.

The devastating complete loss of hand function after more proximal amputations to the palm, wrist, and distal forearm necessitates an attempt at replantation whenever possible, especially in light of the relative ease of repair of larger vessels and nerves, the facility of bone shortening and stabilization with or without wrist arthrodesis, and the generally diminished adhesions limiting excursion in comparison with digital replantation.

A special attempt is made in pediatric patients to replant whenever possible, as children have a prolonged life expectancy; an enhanced regenerative capacity, especially with respect to nerve function; and superior ability to adapt to remaining functional deficits.

Contraindications

Relative contraindications to replantation include prolonged warm ischemia time, a single-border digit, a crush or avulsion injury, and inadvertent freezing of the amputated part. Prolonged warm ischemia time, defined as more than 12 hours for digits

where muscle is absent or more than 6 hours for more proximal sites where muscle is present, is often associated with replantation failure. As mentioned previously, a single-border digit is often a poor candidate for replantation; a resultant stiff and/or insensate index finger is often bypassed by the thumb to the long finger, and a stiff little finger may detract from good grip strength.

Crush injury results in severe local damage to all tissue components and often precludes satisfactory function postoperatively, especially with respect to formation of adhesions and consequent limitation of motion. Avulsion injury is commonly associated with extensive damage to vessels, nerves, and musculotendinous junctions for great distances beyond the injury site; such damage may be undetectable at the time of surgery, militating against successful restoration of viability and function.

Placement of the amputated digit directly onto ice may result in freezing. Permanent tissue damage, precluding a successful result, is a consequence of direct cellular injury due to the formation of ice crystals, capillary damage with thrombus formation, and vasoconstriction due to increased sympathetic tone.

Contraindications to replantation include multilevel or segmental injury, a single digit proximal to the FDS insertion, a severe crush or mangling injury, extreme contamination, prior impaired function, concomitant life-threatening injury, severe medical problems, anesthetic risk, and major psychiatric disorder. The ability to successfully reconstruct multilevel or segmental injury is severely limited due to the amount of tissue damage involved. Replantation of a single digit proximal to the FDS insertion (a zone II flexor tendon injury) is associated with poor results related to the loss of PIP joint motion due to flexor sheath adhesion formation.

A severe crush or mangling injury is associated with serious damage to tissues, which are at risk for infection, problematic healing, and scarring, thereby contributing to a poor outcome. Extreme contamination from injuries occurring on the farm and/or in the barnyard in particular may result in serious, sometimes life-threatening, infection. Prior impaired function due to previous damage or concurrent disease affecting the amputated limb may further contribute to functional limitations after replantation.

With concomitant life-threatening injury, first priority should be given to the survival and well-being of the patient in general, with replantation efforts playing a secondary role. In patients with severe medical problems, the risk of increased morbidity resulting from hemorrhage, metabolic disturbances, further hospitalization, or additional surgery must be weighed against the benefits of replantation. Additionally, the anesthetic risk of a prolonged procedure, particularly in a patient with severe cardiac and/or pulmonary disease, must be assessed.

Patients who exhibit a major psychiatric disorder, are unable to comply with initial postoperative instructions (e.g., maintenance of elevation and relative sedation and avoidance of smoking and caffeine), and are unable or not motivated to follow through with intensive therapy are generally unsuitable candidates for replantation surgery.

Results

The success of replantation efforts may be evaluated in terms of viability, function, cold intolerance, physeal growth, need for subsequent surgery, and psychiatric issues. Modern microsurgery has produced viability rates for digital replantation approaching 90%.[3-7] Lower rates are generally associated with injuries involving significant crush or avulsion, those involving multiple digits, and those occurring in children.[16]

Function can be assessed in terms of range of motion, sensibility, and activities of daily living. Range of motion is generally estimated to be approximately 50% of normal and is primarily dependent on the level of amputation.[16] In one series of isolated digital replants, those distal to the FDS insertion demonstrated on average 82 degrees of PIP joint motion.[4] In contrast, in the same series, replants proximal to the FDS insertion yielded only 35 degrees of PIP joint motion and were regarded by the patient as a hindrance to function; injuries at that site are now considered poor candidates for replantation.

Loss of sensibility is often a major source of dysfunction after replantation and is more pronounced in patients with crush or avulsion injuries, older patients, and patients with more proximal levels of amputation.[17] Nevertheless, sensory results after digital replantation approach those seen with primary neurorrhaphy of isolated nerve lacerations.[10] In a series review, 60% of thumb replants and 50% of digital replants were capable of useful two-point discrimination between 7 and 15 mm.[17]

A functional study of 111 thumb amputations treated with replantation or amputation revision demonstrated that 80% of each group performed activities-of-daily-living tasks at a level representing 80% of the capability of the contralateral noninjured thumb, with no sub-

stantial difference between the two treatment groups overall.[18] Pinch strength was higher in the amputation revision group (91% vs 68%). Dexterity was superior in the replantation group.

Another study involving functional assessment demonstrated increased grip strength with multiple digital replantations but only minimal functional advantage.[19] In that study, little justification was found for isolated digital replantation.

Symptoms of cold intolerance may be quite severe initially but usually abate within 2 years and are less of a problem in pediatric patients.[14,17] In one study, cold intolerance with thumb replantation was reported at a rate twice that seen for thumb revision.[18] This alteration in thermoregulation appears to be a complex interaction involving neural, vascular, and metabolic mechanisms.[17] Longitudinal physeal growth in pediatric replants is fairly well maintained. In one series,[14] overall growth of the replanted digits averaged 81% of normal length at maturity, and a growth rate of 93% was measured for the remaining noninjured physes.

During the initial hospitalization, the patient may require subsequent surgery, most commonly for vascular complications due to thrombosis (i.e., arterial insufficiency or venous congestion). Salvage is often possible; a 50% success rate was reported in a series of 42 thumb replantations.[7] The patient may also undergo surgery for treatment of infection or, in the case of a failed replant, revision amputation. Later surgical intervention is usually reconstructive in nature and may include procedures for soft-tissue coverage, contracture release, tenolysis, malunion, nonunion, and revision amputation, particularly if functional status can be substantially improved.[10]

Little research has been devoted to the psychiatric issues encountered in replant patients. One study found a 33% incidence of psychopathologic disorders before amputation, with 20% of patients having a substance abuse disorder.[20] In addition, 50% were found to have had a stressful life event prior to the accident, and 60% warranted psychiatric intervention. Postoperatively, an adverse emotional reaction was associated with a preaccident psychopathologic condition, previous psychiatric history, stressful life event, and family or marital dysfunction. Specific stress-related factors in replant patients resulted from a perception that their condition was life-threatening, with symptoms of posttraumatic stress disorder; uncertainty and apprehension about their situation; disturbance of their internal body image, with fear of altered appearance, rejection by friends and family, impaired function, and loss of income; and a tendency to magnify minor changes or problems due to the heightened surveillance by medical staff postoperatively.

Summary

The era of microsurgery has brought with it the technologic ability to replant body parts almost as a matter of routine with fairly reliable success in terms of viability. However, a satisfactory functional result is much more difficult to attain and depends on a variety of factors. The decision to replant is thus a complex issue that relies heavily on surgical judgment and experience.[21] In the final analysis, careful evaluation of the injury and an informed discussion with the patient will yield the best results, although the latter is admittedly difficult given the emotional state of the patient and family immediately after amputation.

Certainly, the alternatives of revision amputation are not without complication either, with persistent pain, tenderness, diminished sensibility, hyperesthesia, cold intolerance, adherent or atrophic skin coverage, shortening, joint stiffness, and loss of the nail being some of the reported problems.[3] Controversy persists regarding replantation at the distal interphalangeal joint or distally, with proponents claiming shorter operative time, diminished morbidity and cost to the patient, and a good cosmetic result compared with more proximal replantation efforts. As technical abilities improve and health care evolves, indications may vary, but ultimately patient selection plays a predominant role in eventual outcome.

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