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Management of a mutilated hand: the current trends

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Abstract

Mutilated upper limbs suffer loss of substance of various tissues with loss of prehension. The most important factor in salvage of a mutilated hand is involvement of a senior surgeon at the time of initial assessment and debridement. A regional block given on arrival helps through assessment and investigations in a pain-free state. Infection still remains the important negative determinant to outcome and is prevented by emergent radical debridement and early soft tissue cover. Radical debridement and secure skeletal stabilization must be achieved on day one in all situations. Dermal substitutes and negative pressure wound therapy are increasingly used but have not substituted regular soft tissue cover techniques. Ability to perform secondary procedures and the increased use of the reconstructed hand with time keeps reconstruction a better option than prosthesis fitting. Toe transfers and free functioning muscle transfers are the two major secondary procedures that have influenced outcomes.

Keywords

Mutilated hand, mangled extremity, microsurgical hand reconstruction, limb salvage

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Introduction

Many definitions exist for a mutilated hand, but the one propounded by Campbell Reid explains the damage to the hand and the goal that we need to set in its management: 'the mutilated hand has suffered a severe injury with *loss of substance* and has been left *lacking in prehension*' (Reid and Tubiana, 1984). Mutilated hands demonstrate varying amounts of loss of substance of skin and soft tissue, musculotendinous units, nerves and blood vessels, and bones. The injury may include digital, partial hand or partial upper limb amputations. Skin and soft tissue loss and skeletal injury are almost always present. The goal is to restore prehension, whereby the thumb should meet the fingers. This article summarizes the current trends of management and details the best practices based on the experience of the authors.

Scores or classifications to decide on salvage or amputation

Scores and classifications help the decision process to evaluate the efficacy of different techniques and compare outcomes. Several classifications exist for mutilated hands. Some are based on the extent of amputation (Wei et al., 2018), and some on the tissues lost (Weinzweig and Weinzweig, 1997). Campbell and Kay (1996) evolved the Hand Injury Severity Score for injuries distal to the carpus, wherein the injuries to each ray are assessed; and using specific weighting factor to each ray, a final number is evolved. A score greater than 50 indicates a mutilated hand. Based on our combined

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experience, we feel that it is difficult to fit every mutilated hand injury into these classifications, and none are helpful in making the amputation versus salvage decision. It is felt that the skill levels and attitude of the surgeon greatly influence the salvage decision and the outcome. It is difficult to incorporate this 'surgeon' factor in any of the scoring systems, and this makes it impossible to develop a score to indicate amputation or salvage.

In injuries proximal to the wrist, if the hand is structurally intact or can be made functional, every attempt is made to salvage. In high volume units, technical impossibility is the only absolute indication for amputation, since with secondary procedures we can obtain at least a basic hand even in severe injuries (Figure S1, Supplementary online). Despite the advancements of the last decade in the arena of upper limb prostheses, the incidence of abandonment of upper limb prosthesis is 50% and higher (Salminger et al., 2020). Most upper limb injuries are unilateral, and they are not candidates for transplantation. Hence the threshold for salvage is higher in injuries at the forearm and arm levels

We are unanimous in the opinion that senior-level input at the time of initial patient assessment and debridement influences the decision to salvage. In borderline situations, the decision to amputate is made at the end of debridement, since from what at first looks unsalvageable might be reconstructable. A basic hand may be salvageable using available structures and incorporating heterotopic replants and fillet flaps. We are convinced that it is difficult and sometimes even risky to make the amputation and salvage decision based on transmitted digital images.

The first steps

Management of a mutilated hand starts at the time of the patient's arrival at the hospital. The system of 'on arrival block, and in theatre resuscitation', followed at Ganga Hospital, India, is a preferred model of care (Sabapathy et al., 2020). All patients with major injuries as judged by the input of the referring doctor, patients with severe blood soakage of the dressings and patients in poor general condition are directly received in the anteroom of the operation theatre. Nothing is done in the emergency room. In the anteroom of the operation theatre, the patient is received by a senior anaesthesiologist, plastic surgeon and orthopaedic surgeon. After a quick survey based on the advanced trauma life support (ATLS) protocol, a brachial plexus block is administered; and in a pain-free state, the dressings are removed. Radiological examination is done after the block is placed, which helps us to get good radiographs without overlap of fractured bones. The same anaesthesia is used for the index procedure. The advantages of this system are that the patient becomes pain-free immediately after arrival, boosts their confidence in the system, ensures immediate senior input, helps obtain good radiographs, facilitates tourniquet application in case of bleeding and ensures a short 'arrival-to operating table' time.

Mutilating injuries produce a psychological and social impact that should be openly and candidly addressed with the patient and their family. Meyer (2003) found that the earlier and the more skilfully these issues are addressed, the more likely it is that psychological factors will not impede functional outcome. The 'on arrival block' system that makes the patient pain free allows us to do this.

Use of this system demands the availability of senior personal and dedicated operating rooms all the time. We feel that obtaining good outcomes in mutilated injuries depend as much on the organizational logistics as the skill levels of the surgical team.

Setting the goals

The goal is to get the patient to as close to pre-injury functional status in the shortest possible time, while minimizing the cost of care. While reaching the pre-injury status may not be possible, we attempt to restore an acceptable hand. This is one with a thumb and at least three fingers of the correct length, with motion preserved at the proximal interphalangeal joints and sensation (del Piñal, 2007). Baltzer and Moran (2016) state that the minimal requirements for the hand are a stable wrist and two opposing, sensate and painless digits. For motion, one digit can be stable and the other being sufficiently mobile to meet the other. Both digits should be sufficiently stable to provide good pinch strength. The gap between the digits determines the size of objects grasped, and so web space creation is important. The goal is the same in extensive proximal injuries, with preservation or reconstruction of painless, stable major joints to position the hand for function.

Debridement

The value of adequate radical debridement as a fundamental requisite for success has not changed with time, but the time to debridement has been debated. The validity of the 6-hour rule for debridement is questioned. An extensive meta-analysis of observational studies used raw and adjusted estimates to determine if there was an association between the timing of initial debridement and infection. It demonstrated an increased risk of infection with

progressive delay in debridement (Foote CJ et al., 2021; Schottel PC, 2021). All studies measure infection as the outcome. We feel that it is not just infection that matters in the overall care of the patient. With a shorter time to the operating room, the duration of pain is reduced, blood loss is less and feeling of uncertainty is reduced in the patient. So, it is important to keep the time to debridement, a surgeon-controlled variable, to the minimum. It can be longer when there is a lack of availability of an operating room or skilled personal, which makes the risk of surgery higher than the benefit provided. The lack of robust evidence for the 6-hour rule must not be used to make debridement an elective procedure.

We feel that barring electrical burn injuries, primary debridement could be the only one necessary for most injuries. Though not against a 'second look', we feel that 90% of the time on our practice, a single debridement suffices.

Consensus is in support of tourniquet, and we use a tourniquet for debridement and recommend wound assessment after release of tourniquet to verify the adequacy of debridement. If there be any doubtful areas, the tourniquet is inflated again, and the area debrided and the sequence is repeated until adequacy of debridement is ensured. In situations of distal ischaemia, adequacy of debridement must be reassessed after revascularization.

We uniformly recommend administration of antibiotics, and most units instil antibiotic on arrival (Ketonis et al., 2017; Warrender et al., 2018). Irrigating solutions have been a subject of debate. Normal saline is the most favoured, and the volume and timing of irrigation is determined by the surgeon. If the wound is highly contaminated, a gentle wash is given to remove large particulate matter. We believe that the best way to remove ingrained small dirt is with a scalpel and perform 'wound excision' as advocated by Godina. Irrigation is performed after primary sharp debridement, since earlier irrigation has the risk of driving contaminants into joints and intermuscular planes. We use a soft bulb to provide low pressure irrigation. Pressure irrigation and pulsatile lavage have not been shown to affect outcome (Heckmann et al., 2020). In Sabapathy's high-volume unit, autoclaved water has been used for wound irrigation for three decades with no difference in outcome but with cost reduction.

How far to go on day 1?

The practice of radical debridement and increasing familiarity with microsurgical free flaps has pushed surgeons to prefer total primary reconstruction. Primary reconstruction is done when one is confident of the adequacy of debridement and the ability to provide soft tissue cover.

On day 1, at least two steps must be completed; they are debridement and skeletal fixation. Even in instances of polytrauma after the management of life-threatening injuries, upper limb debridement and skeletal fixation is done. Failure results in increased morbidity, including infections. If there is distal ischaemia, revascularization must be done. Even when the limb appears viable, if the major vessel is injured and pulsatile blood flow is not present, revascularization is advised. Good pulsatile distal blood flow ensures viability, facilitates survival of local flaps and preserves more options for future reconstruction. Flow-through flaps are good options, which also enable immediate soft tissue cover. They are particularly useful for small defects in the hand (Lee et al., 2019). In major injuries, the length of the vessel defect and the extent of the soft tissue defect make flow-through flaps less practical. Often the vessel defect is vein grafted, and a separate flap cover is provided. Skeletal stabilization is done prior to revascularization.

The methods of skeletal fixation in mutilated upper limb injuries have not changed over the last three decades. In viable upper limbs, it is good to concentrate on stable fracture fixation, and we advise internal fixation with plates and screws for the long bones and K-wires for the hand skeleton. Internal fixation is safe and the risk of infection in hand fractures is low (Ketonis et al., 2017). In demanding situations, acute primary shortening and creation of one bone forearm is a good option. (Devendra et al., 2019; Kusnezov et al., 2015). Shortening up to 10 cm is well tolerated in the upper limb, and this offers the advantage of radical debridement, direct repair of vessels and nerves, and primary wound closure (Figure 1). External fixators are less preferred since they may hinder flap coverage.

Timing of soft tissue cover

Analysis of our practices and study of the literature does not provide a time by which soft tissue cover must be completed, except we agree that it is best to do it as early as possible. 'Early' is influenced more by local logistics than by science. This usually means between 24 and 72 hours, certainly within 5 days. With good debridement and antibiotic coverage, practice has shifted away from emergency flap coverage, except in situations where vascular repairs or vein grafts are exposed; then immediate flap cover becomes mandatory. In instances of exposures of critical neurovascular structures, some of us use acellular dermal matrix as temporary cover (Ali

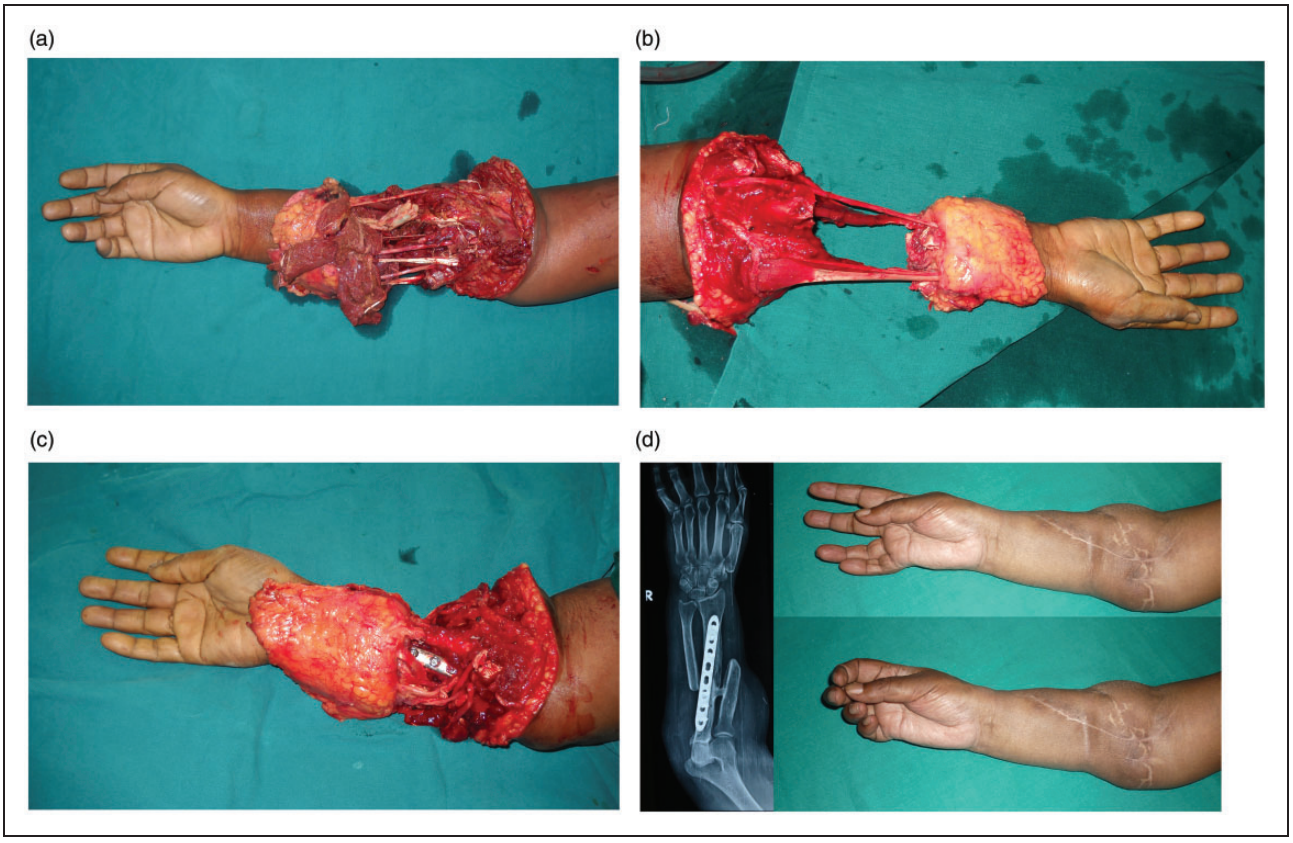

Figure 1. (a) Crush injury forearm following a road traffic accident in a 40-year-old diabetic lady with extensive contamination, segmental fractures and distal non-viability. (b) Post debridement picture. Median and ulnar nerves, extensor carpi radialis longus and slip of extensor digitorum communis were intact. (c) Creation of one bone forearm, with plating of proximal ulna to distal radius with excision of devitalized bone, revascularization with repair of radial, ulnar arteries and venae commitantes, cephalic vein and en masse repair of flexors and plication of intact tendons. (d) Postoperative radiograph showing union of bones with the hand capable of pinch and grip. The limb is shorter by 10 cm but not apparent at work.

et al., 2020), although we feel flap cover is safer. Negative pressure wound therapy (NPWT) as a temporary cover is used less often in the management of mutilated hands than it is for mutilated lower limbs. NPWT is an ideal solution when the general condition of a polytraumatized patient requires delay of definitive soft tissue coverage.

Type of soft tissue cover

Most mutilated injuries need flap coverage to protect exposed critical structures. There is a wide array of flaps to choose from. Free flaps can be tailored to provide a good functional and aesthetic outcome for almost any defect (del Piñal, 2020). Muscle flaps have the advantage of filling up cavities brought about by debridement (del Piñal et al., 2006b), while skin flaps are preferred when there is a possible need for access to secondary procedures. In major circumferential injuries, the critical areas and the pathway of future reconstruction are covered with flaps, and the rest with grafts. There have been no differences in infection rates between pedicled and free flaps and muscle and skin flaps, which stresses the role of good debridement before flap coverage. Ultimately the choice depends upon a complex interplay of patient, defect and surgeon-specific factors (Ng et al., 2015), with surgeon's training and familiarity being the most important determinant (Venkatramani et al., 2019a) With refinements of techniques, even total primary reconstruction is possible using pedicled flap coverage (Sabapathy et al., 2008).

Management of composite defects

Advanced anatomical understanding has led to the development of numerous composite flaps (del Piñal et al., 2006a). The common composite flap used in mutilated injuries is the free fibula flap, which can be harvested with a large skin flap.

Figure 2. (a) Industrial accident with sub-total amputation of ring and little fingers with loss of vascularity, avulsion of flexors and segmental loss of ulnar nerve. (b) Post-revascularization of ring and little fingers by repair of the ulnar artery, the dorsal defect was primarily covered by posterior interosseous flap. (c) Secondary reconstruction of flexors to ring and little with tendon graft and nerve graft reconstruction of ulnar nerve with sural nerve graft. (d) Good functional result 6 months later.

Division of the bone into multiple segments allows reconstruction of multiple metacarpal defects. In practice, few defects in our experience are managed by composite flaps, the principal reason being that the geometry of the defects of the individual component makes it difficult to plan a composite flap. Each defect is individually reconstructed in the best possible manner.

The iliac crest continues to be the main source of non-vascularized bone graft, with medial femoral condyle and fibula being the source for vascularized bone grafts, the former for small defects and the latter for longer defects. For multiple large defects in tendons, fascia lata is a good donor source (Sabapathy and Bhardwaj, 2013).

Secondary procedures

Capability of doing secondary procedures has extended the primary indications of salvage (Foo

Table 1. Summary.

A mutilating hand injury is a severe injury with tissue loss that results in loss of prehension.
The most important factor in salvage of a mutilated hand is involvement of a senior surgeon at initial assessment and debridement.
An early regional block can facilitate pain-free assessment and investigation.
The goal of reconstruction is a stable wrist with at least two opposable sensate digits and a wide web.
Early antibiotic administration, emergent radical debridement with low pressure lavage under tourniquet control and stable skeletal fixation are immediate priorities.
Aim to complete soft tissue cover within 5 days.
Address obligatory secondary procedures within 6 months and discretionary procedures to improve function and appearance once tissue equilibrium is achieved.
The most important factor determining outcome is infection.

and Sebastin, 2016). Secondary procedures are divided into obligatory procedures, which are used to complete the reconstruction or address complications and discretionary procedures to improve function and appearance. Obligatory procedures such as those to bridge gaps in bone, tendon and nerve, are done earlier, within 6 months. Discretionary procedures are done after 6 months when the tissues have reached equilibrium, which is evidenced by reduction in induration along the pathway of reconstruction (Figure 2).

Toe transfers (Sabapathy et al., 2013; Wei et al., 1993) and free functioning muscle transfers (Venkatramani et al., 2019b) are secondary procedures that have maximally influenced the outcome in mutilated hand injuries.

Measuring outcomes

Upper extremity use is linked to economic growth and productivity and so accurately measuring the outcomes of mutilated upper limb injury is of importance, particularly to the developing world where these injuries predominantly occur. Patient-reported outcomes (PROs) are used for all hand conditions, but the social infrastructure and lack of insurance support may push the patient to different levels of motivation to get back to work. So, the responses differ between higher and lower income countries. The variability inherent in the severity of injuries, the treatment approaches and the rehabilitation protocols make it difficult to compare. In addition, the data available from the developing world is of inconsistent quality to make any meaningful measure of outcomes and suggest sweeping changes. Giladi et al. (2016) have also rightly stressed the importance of local language questionnaires that reflect local cultural and social practices to measure PROs in mutilated upper limb injuries.

Kovacs et al. (2011) found that PROs after upper extremity trauma, when followed over time, often show improvement in health-related quality of life. Though it is partly due to recovery, it is also related to patients adjusting to the condition (Chan and Spencer, 2004). These two factors push the indications for salvage.

Factors determining outcomes

Infection is the single negative factor influencing outcome. It leads to increased tissue loss along with multiple procedures and escalation in cost and duration of care. Radical debridement and early soft tissue cover are the mainstays to prevent infection. Quality of debridement, revascularization, use of spare parts, which otherwise would have been discarded, are influenced by the availability of senior surgeon at the time of the index procedure, and this is an outcome determinant.

A study (Giladi et al., 2017) of 46 patients with massive proximal upper extremity reconstruction done in a resource-limited setting found that this cohort had an average Michigan Hand Questionnaire score of 79 (standard deviation (SD) 15) and mean Disability of the Arm Shoulder Hand score of 13 (SD 15), which are not significantly different than scores for long-term outcomes after other complex upper extremity procedures. The following factors predicted PROs and functional performance after reconstruction: extent of soft tissue reconstruction, multi-segmental ulna fractures, median nerve injury, and ability for patients to return to work and maintain their job after injury.

The speciality of hand surgery has evolved with the management of mutilating hand injuries. The keys in clinical decision making for the multilated hand are summarized in Table 1. Basic principles of early debridement, skeletal stabilization and skin cover have not changed, but the technical advancements in microsurgery and the feasibility of secondary procedures have extended the indications for salvage and enhanced the outcomes achieved. Even in the most complex combined injuries, intelligent reconstruction will obtain acceptable outcomes, making the efforts of salvage worthwhile (Sabapathy et al., 2016).

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