War Injuries of the Hand

16

Shalom Stahl and Edward Calif

16.1 Introduction

War injuries of the hand cause great morbidity and loss in manpower. Because these wounds are not fatal and often apparently innocuous, the priority level for evacuation and early surgery is low. In patients with complex multiple injuries, treatment of the hand injury receives little or no priority.

Body armor and helmets have reduced the mortality of injuries to the torso and head while leaving the extremities vulnerable to injuries caused by roadside bombs, shrapnel, and other explosive ordnance. The result is that many wounded are occasionally left with debilitating injuries to the limbs. These injuries are difficult to manage since they combine severe soft tissue, bone and vascular injuries, often leaving military surgeons with the decision to amputate or attempt to salvage a severely injured limb. Future provision of military protective gear should be directed to outfitting soldiers with flexible, flame-retardant gloves that serve to protect the hand and wrist while allowing for dexterity [6]. The development of hand surgery as a specialty has been closely linked to military surgery and surgeons, particularly in the USA, and since World War II [2, 15].

Hand injuries are common and may constitute considerable workload and impact on the military population as a result of the large number of patients who are placed on restricted duties following hand trauma, and those who require aeromedical evacuation for further treatment. The concept of damage control surgery has found particular application in the military environment. Casualties are evacuated from the point of wounding to an appropriate point of care. This evacuation is channeled through a succession of facilities of increasing medical capability.

Injuries to the hand are of particular significance since they limit function. There is a clear relationship between occupation and predisposition to hand injuries. Manual workers have been identified as being at particular risk [10, 17]. The nature of the work undertaken by military personnel on operations is often manual and physical and predisposes to hand trauma. Risks vary for different occupational roles within the military. Military personnel on operations are also required to handle personal weapons and to operate armored vehicles, often in proximity to other soldiers and the local civilian population. It may be necessary to adopt a lower threshold than normal for hospital admission, or close supervision, in order to include a margin for safety. The majority of the hand injuries treated in this environment do not require a hand surgeon and most do not require hospital admission.

Principles for the management of war wounds have remained consistent since the concepts advanced by Larrey [20]. Thorough debridement and management of the soft tissues are vital. Staged surgery has found particular application in the management of war wounds [3]. Even when adequate debridement is achieved in the field, internal fixation is usually avoided in these circumstances due to the risks of infection [16]. The selection of wounds for primary closure requires judgment and confidence in the original debridement. Where there is doubt, debridement and delayed closure is a sound approach.

S. Stahl (✉)
Rambam Health Care Campus and Bruce Rappaport, Faculty of Medicine, Technion, Israel Institute of Technology, Haifa, Israel
e-mail: s_stahl@rambam.health.gov.il

E. Calif
Hand Surgery Unit, Rambam Health Care Campus, Haifa, Israel
e-mail: edikal@hotmail.com

A. Lerner and M. Soudry (eds.), *Armed Conflict Injuries to the Extremities*,
DOI: 10.1007/978-3-642-16155-1_16, © Springer-Verlag Berlin Heidelberg 2011

Military surgeons and emergency medicine physicians should be adequately trained in, and prepared for, the initial management of hand trauma, whatever their parent specialty. Definitive treatment may require consultation with a specialist hand surgeon. There are few specialist hand surgeons in the military and their availability cannot be guaranteed.

The general principles of war surgery apply equally to all parts of the body, but there are special emphases when applied to the hand. Because of the potentially serious and occasionally devastating consequences of any hand injury, however apparently trivial, an orderly and thoughtful approach to treatment is mandatory. Since the disability potential of hand injuries is so great, and the danger of iatrogenic damage so real, all war hand surgery should preferably be performed by experienced hand surgeons. Unfortunately, this is often not feasible, which underscores the importance of the frontline care-provider having knowledge of hand wound management and treatment. A manual briefly detailing the principles of war surgery of the hand should be available in all field stations and primary care hospitals so that less experienced surgeons may have a ready reference.

The surgeon operating on a hand wounded by a high-velocity missile usually has to deal with extensive soft tissue damage and comminuted fractured bone. Often, definitive primary excision cannot be performed because the extent of tissue death is greater than what the primary appearance suggests.

16.2 Primary Care of the Wounded Hand

When a hand injury is accompanied by shock and no other external injuries are apparent, internal injuries should be sought and definitive treatment of the hand injury delayed until the cause of shock has been defined. Once the casualty has been resuscitated and major injuries dealt with, definitive primary treatment of the hand should be commenced without delay. Any constrictive objects, such as rings and watches, should be removed immediately. Sterile dressings are applied to the wounds, with sterile dry pads placed in the web spaces between the fingers to avoid skin maceration. Copious cotton is wrapped lightly around the hand, which is then splinted in any comfortable position since the preferable intrinsic-plus position is not often practicable. Ideally, the hand should be supported in the position of function with the wrist dorsiflexed approximately 30°, the metacarpo-phalangeal joints in 70° flexion, and the interphalangeal joints in 10° flexion. The thumb is supported in 45° of palmar abduction and slight flexion. Bandaging should be very light, and no pressure should be placed on the wounded limb. The limb is supported in a sling. Emergency tourniquets usually are not necessary. They are applied only if firm local pressure does not stop the bleeding and the patient is taken to the operating room. In severe crush and burn injuries, potent analgesics should be given. Primary care of the wounded hand should adhere to the following practical guidelines:

1. Observe the general principles of resuscitation as to airway control and bleeding control. The inability to surgically control life-threatening hemorrhage may necessitate the use of tourniquets or urgent amputation.
2. Early administration of systemic antibiotics (cephalosporin) is important, especially when war wounds cannot have timely surgical treatment. Tetanus toxoid is administered in accordance with the patient's history of immunization.
3. Depending on surgical and anesthetic capability, operative treatment of wounds may be limited to local anesthesia and wound debridement to remove debris or incision to improve drainage. If wound incision or debridement is elected in the absence of blood-transfusion capability, care should be exercised to avoid hemorrhage.
4. Remove easily accessible foreign bodies and detached pieces of tissue, and irrigate wounds. Inspect the track to remove debris and excise clearly nonviable tissue at both the entry and exit wounds. Debridement should be judicious rather than radical, and only clearly devitalized tissues are excised. Every bit of viable tissue should be preserved.
5. Leaving wounds widely open after debridement (including an apparently clean wound) is of prime importance. However, exposed joint capsules, tendons, bone, and neurovascular structures require special consideration.

6. Simple dressing should be applied, allowing drainage.
7. Delayed closure is carried out when wounds appear clinically clean, usually 4–10 days following debridement.

Hand injuries may be overlooked in polytrauma cases. Life-threatening priorities may dictate deferral of treatment of the injured hand. Adequate dressing and limb immobilization may prevent further damage and blood loss. The limb is elevated, and systemic antibiotics are instituted. Hemostasis should be carefully accomplished with intermittent application of the tourniquet. Devitalized muscles, skin, debris, easily accessible foreign bodies, and grossly contaminated bone fragments are removed.

16.3 Tourniquet-Related Morbidity

Improper or prolonged placement of a tourniquet due to poor medical training can lead to serious injuries, such as nerve paralysis and limb ischemia (Fig. 16.1a, b). There is a need for improved training among medical personnel in the use of tourniquets, as well as a need for an adjustable-pressure, commercial-type sphygmomanometer cuff with a large surface area that is appropriate for application to all limb parts. The need for continued blood occlusion should be repeatedly evaluated by intermittent release of the tourniquet and assessment of the bleeding.

16.4 Advanced Primary Management

16.4.1 Reassessment: General and Local

In the hospital, systemic reassessment is performed and therapeutic priorities are determined. Major life-threatening injuries take precedence. The injured hand is meticulously inspected for viability of skin, bone, blood vessels, tendons, and nerves. Radiographs are performed to define any bony damage, fractures, dislocations, bone loss, and embedded foreign bodies (Figs. 16.2a–c and 16.3). Patients with "soft" signs of vascular injury should preferentially be further evaluated by duplex ultrasonography or CT angiography.

16.4.2 Anesthesia

General anesthesia is safe and useful when required for surgery on multiple limbs and organs. In isolated hand injuries, regional anesthesia is preferred. Regional anesthesia has fewer disturbances when compared to general anesthesia. Sympathetic block accompanying

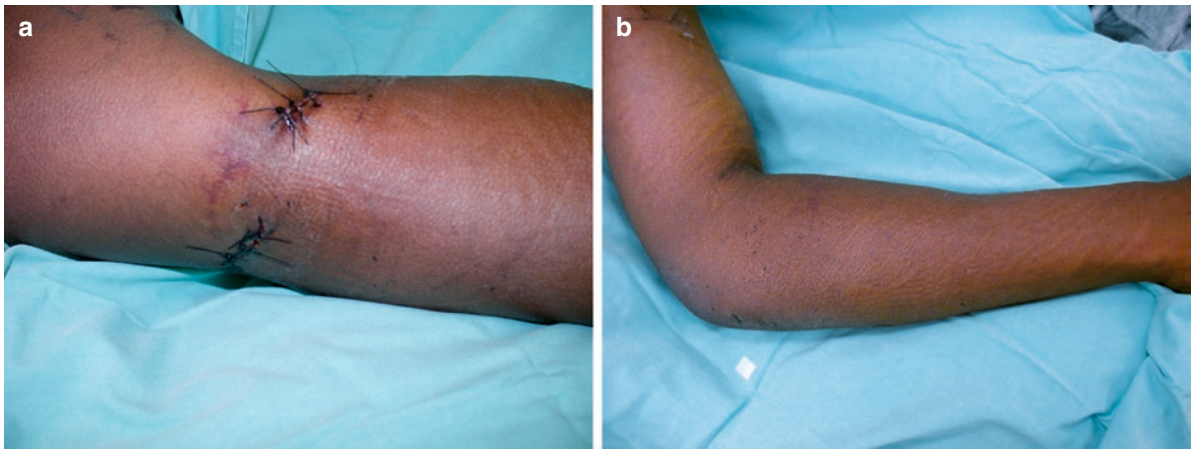

Fig. 16.1 (**a, b**) An emergency tourniquet placed at battle field, was removed few hours later. The soldier had prolonged multiple peripheral nerve palsy. Notice the local ecchymosis and edema distal to the occlusion site

Fig. 16.2 (**a**–**c**) Apparently innocent shrapnel wounds concealed retained foreign bodies and digital nerves injuries

Fig. 16.3 Multiple rocket-shrapnel injuries of the palm

peripheral nerve block improves blood flow, prevents tissue hypoxia, and enhances healing. Regional anesthesia provides prolonged postoperative analgesia and decreases the need for narcotics. Supraclavicular, interscalene, brachial plexus, and axillary blocks are preferable to local infiltrations. By employing regional anesthesia, the need for advanced monitoring is avoided. Prolonged anesthesia and sympathetic block can be provided with continuous block.

16.4.3 Primary Wound Excision

Adequate and safe primary excision requires good light, a set of fine instruments, adequate analgesia, and pneumatic tourniquet. Visual magnification may be of a great help. The limb and wounds are flushed with copious amounts of sterile balanced solution. Irrigation evacuates debris, blood clots, and foreign materials. Jet lavage instrument may be helpful.

A tourniquet can be used during the debridement to minimize blood loss. The tourniquet guarantees good vision and enables the identification of delicate structures but should be released intermittently to assess the viability and vascularity of retained tissues (Fig. 16.4a–c). Continuous arterial occlusion should not exceed 1 h. All devitalized tissues should be excised to avoid infection and prevent later toxicity by necrotic tissues. Only living tissue can defend itself from bacterial invasion and multiplication [13].

16.4.3.1 Skin

Wound edges are not automatically excised; only those parts are excised that are definitely dead. The texture and color of the skin and the amount of bleeding from the edges and capillary filling after tourniquet release are useful indicators in decision-making (Fig. 16.5a, b). Skin edges are often ingrained with gun powder or dirt and tissue viability is rendered doubtful. Skin with marginal viability is retained. Repeated assessment is needed at 48-h intervals until wounds are clean.

Carpal tunnel decompression is commonly performed in severe hand injuries to avoid acute compression of the median nerve. Whenever compartment syndrome is suspected, formal open fasciotomies should also be performed on the dorsum of the hand and forearm without delay (Fig. 16.6a–c). Fasciotomy incisions are planned so as not to compromise surgical approaches that may be required later.

16.4.3.2 Subcutaneous Tissues and Muscles

The principle of minimal excision applies equally to these structures. Irretrievably damaged muscles and totally shredded, crushed, or avulsed tendons are removed. Frayed tendon ends are trimmed smooth and preserved. Muscle viability is determined by its response to electrical stimulation. Special attention must be paid to hemostasis. Hematomas, like any other devitalized tissue, are defenseless against infection.

16.4.3.3 Vascular Structures

Injuries of either the radial or ulnar artery may be safely ligated, especially in polytrauma cases, since both have rich distal anastomoses. However, both arteries cannot be ligated without danger of ischemic necrosis in the hand. Since the radial or ulnar artery is absent in about 5% of the population, an attempt should be made to re-establish continuity, especially if both arteries are injured. Injured arteries are best reconstructed by end-to-end anastomosis after adequate excision of damaged ends. Other options for vascular reconstruction include endovascular intervention, vein interposition grafting, and primary bone shortening followed by primary vascular anastomosis. Severance

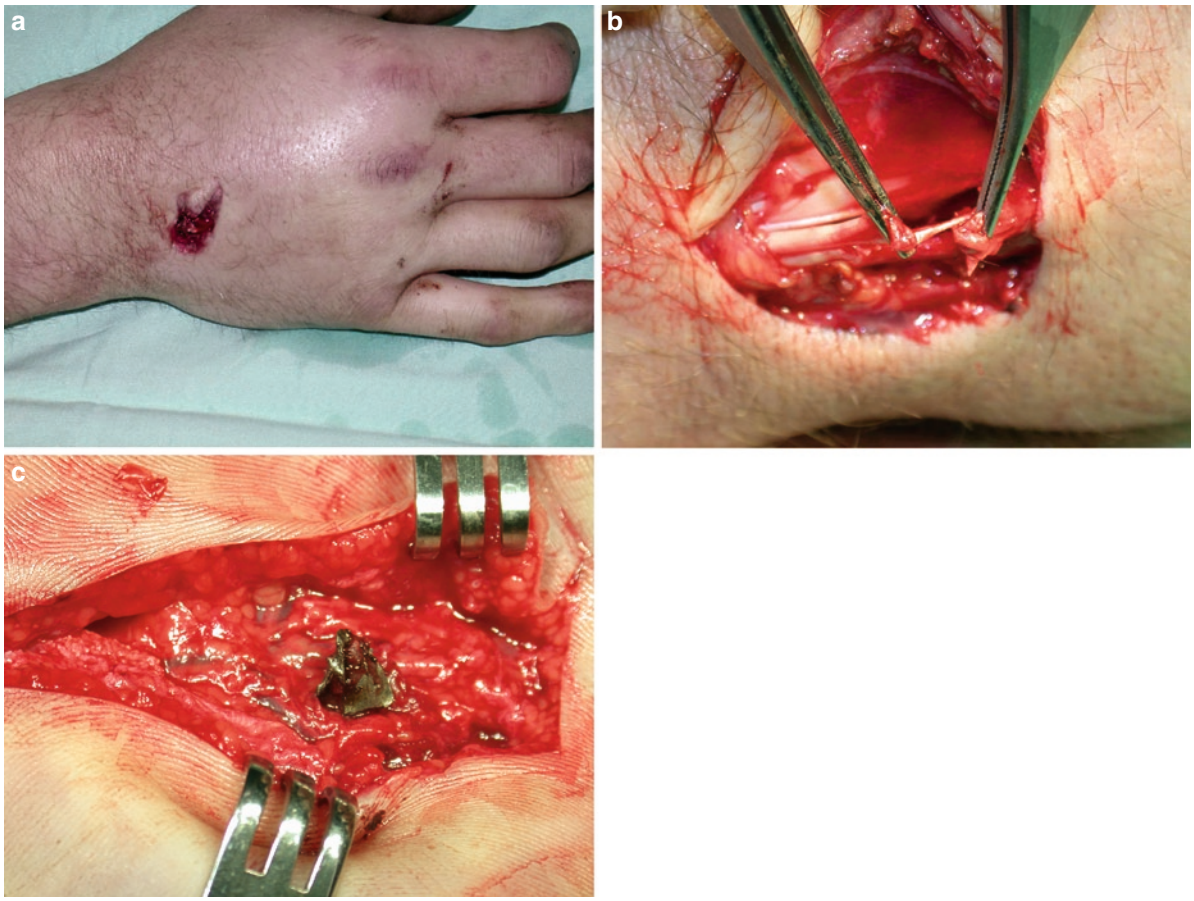

Fig. 16.4 (**a**–**c**) Entrance wound caused by shrapnel. During debridement, lacerated extensor tendons were observed. The shrapnel had traversed the hand and was embedded in the palm

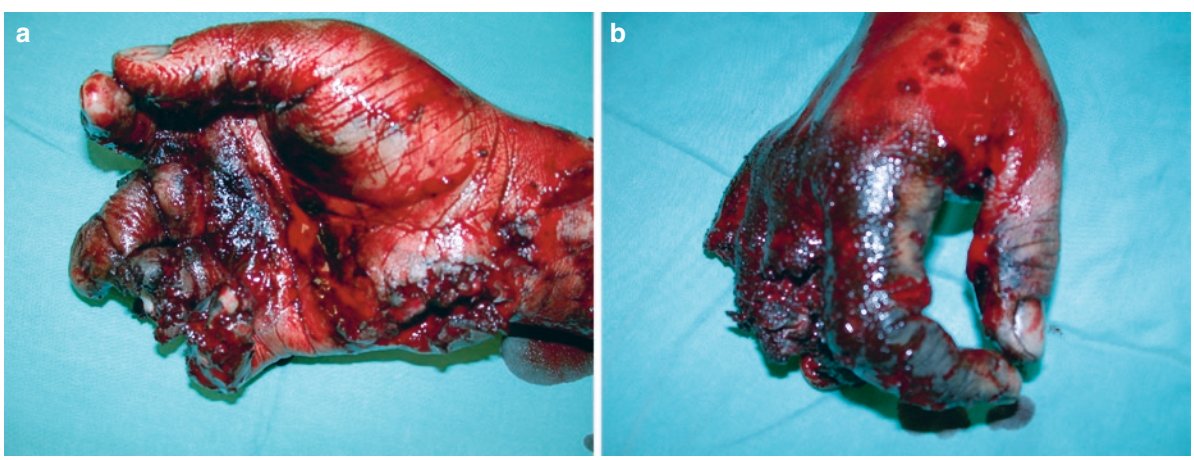

Fig. 16.5 (**a, b**) Extensive tissue damage cause by blast injury. Notice the signs of thermal injury which complicates soft tissue healing

Fig. 16.6 (**a**–**c**) Compartment syndrome of the volar forearm, was addressed by immediate fasciotomy. Judicious approximation of skin edges enabled subsequent delayed primary wound closure

of the dorsal venous network of the hand may result in persistent chronic edema of the hand. Venous reconstruction may be necessary when most of the major dorsal vein has been damaged.

16.4.3.4 Nerves

Nerves should be identified and carefully inspected, preferably with the aid of visual magnification. Partially lacerated nerves are approximated and may be repaired. If the nerve is not found in continuity, the lacerated ends should be clearly marked and primarily sutured to surrounding tissues when possible to prevent retraction. Direct repair or nerve grafting is risky in a contaminated or infected area.

16.4.3.5 Bone

Bone is preserved except for grossly contaminated detached cortical fragments not essential for structural stability. Bony fragments having the flimsiest soft-tissue attachment are retained. Anatomic reduction of fractures at this stage is unnecessary and may be unsafe (Figs. 16.7a–f and 16.8a–f). Readily accessible foreign bodies are removed, but meticulous evacuation of small embedded particles is not essential.

War fractures are almost always open and comminuted fractures, usually presenting with both fragment displacement and bone deficit. This pattern of injury makes reduction and proper fixation difficult to achieve, and delayed bony union should always be expected, especially if the injury is complicated by infection.

Fig. 16.7 (**a**–**f**) Shrapnel injury with open metacarpal fractures, managed by early debridement and internal fixation. Subsequently, a radial artery flap was employed for definitive wound closure

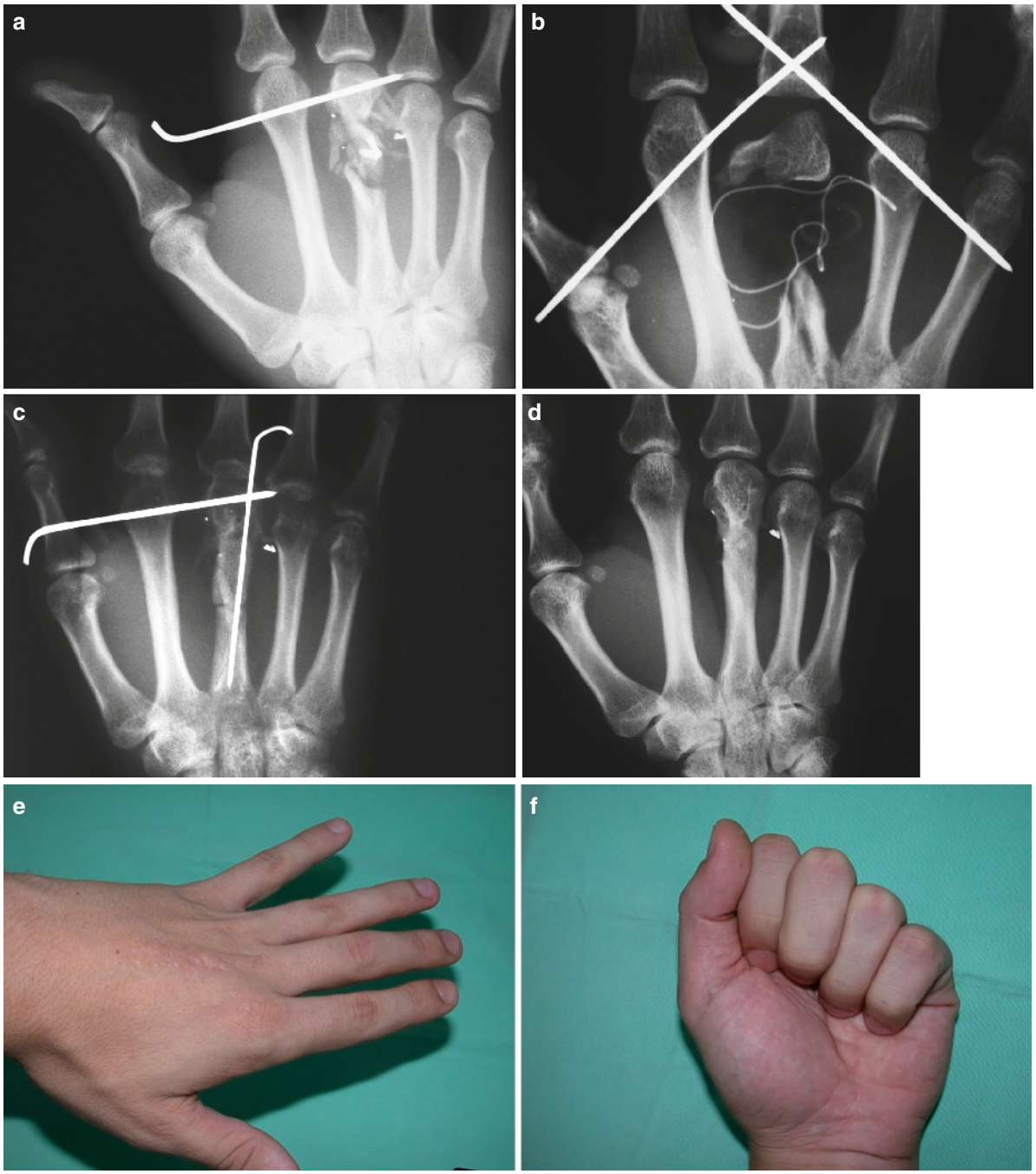

Fig. 16.8 (**a**–**f**) An open comminuted fracture of the third metacarpal bone. Stepwise management included debridement, internal fixation by a trans-metacarpal Kirschner's wires, followed by late bone autografting. Good bony incorporation and functional results were achieved

Addressing the fracture should be within the context of the injured hand. War injuries may be devastating, and the optimal management should be guided by modest objectives dictated by functional rather than anatomical outcome. A severely traumatized hand must be stabilized. Battle injuries of the hand typically exhibit unstable fracture patterns requiring surgical stabilization. The choice of fixation device depends on several factors, including the type and location of the fracture, the severity of soft tissue damage, and subsequent soft tissue coverage requirements [1]. Stable fixation followed by bony union helps to control pain, provides a secure platform for soft tissue healing, resolution of edema, early tendon and articular mobilization, and allows effective rehabilitation. Stable fixation of open fractures also acts as a deterrent to infection. Awaiting solid bony consolidation before mobilization may jeopardize ultimate functional outcome, and may render the hand stable but worthless.

The type of fixation should be that which is most efficient and most readily applicable under the circumstances. The Kirschner-wire technique is the easiest. Comminuted fractures are challenging. Primary skeletal rigidity enables the surgeon to proceed with tendon and nerve surgery, and prevents the collapse and shortening of the skeletal frame. However, it is hard to achieve stable and durable direct reduction and fixation of fragments using Kirschner wires or cerclage wires. Skeletal traction or external fixation may be required for attaining alignment and stability, bridging comminuted fragments or bone deficits [5]. External fixation, the least invasive form of surgical skeletal fixation, is a widely accepted form of treatment for the severely traumatized extremity. A severely injured soft-tissue envelope will not tolerate acute extensive surgical dissection. Placement of an external fixator stabilizes the skeleton, provides excellent soft-tissue access [18], and allows adequate wound care. Internal fixation with rigid fixation is usually reserved for areas of healthy clean soft tissue, which is able to be closed.

Transarticular fixation should be removed or substituted as early as possible to avoid joint stiffness. Transmetacarpal fixation using transverse percutaneous Kirschner wires, bridging plates, external fixators, a spacer Kirschner-wire, or antibiotic-laden cement spacer may be utilized for bridging bone deficits, maintaining the resultant gaps, and preserving length. Fresh cancellous bone can be placed in the defect. Maintenance of length allows the remaining musculature to function under normal tension. Definitive management may include structural corticocancellous bone grafting.

Early corticocancellous bone grafting of an injured hand could be used in selected cases with well-debrided, surgically clean wounds as long as there is a rich blood supply. Adequate bone fixation, soft tissue coverage, and broad-spectrum antibiotics given intravenously will remove the risk of infection. Hand architecture is corrected while wound contracture and secondary deformity are avoided [1].

Fractures involving joint surfaces should always be reduced and internally fixed when technically feasible. The surgeon may contemplate attaining rigid fixation using plates and interfragmentary screws. However, screws and plates may be rather bulky in fixating phalangeal fractures, may cause stiffness, and may interfere with the functioning of adjacent tendons or irritate nerves. Flexible intramedullary rods can provide stable fixation while minimizing the extent of soft tissue trauma. Irreparably destroyed joints, especially interphalangeal joints and thumb metacarpophalangeal joints, often require delayed primary arthrodesis.

The wrist joint in war surgery is occasionally doomed at presentation. Even though its fate is often arthrodesis, surgeons feel reluctant to employ this procedure at an early stage because of the rather long immobilization required. In less severe injuries to the wrist, the surgeon should try to restore articular alignment and regain length in order to preserve even a small amount of wrist motion. Wrist fusion is reserved as a final resort.

16.4.3.6 Amputation

Every effort should be made to avoid amputation, as currently available prosthetic hands provide only minimal function. Only irreversibly damaged fingers are amputated (Fig. 16.9a–c). Thumb amputation should be regarded a last resort, contemplated only when rendered beyond salvage at repeated evaluations. It is sometimes possible to preserve skin flaps and pedicles for reconstruction and coverage. Finger-tip amputations usually can be managed with topical antibiotics and local care until secondary healing is complete.

The decision of digit amputation should be preceded by repeated evaluations. Amputation is indicated

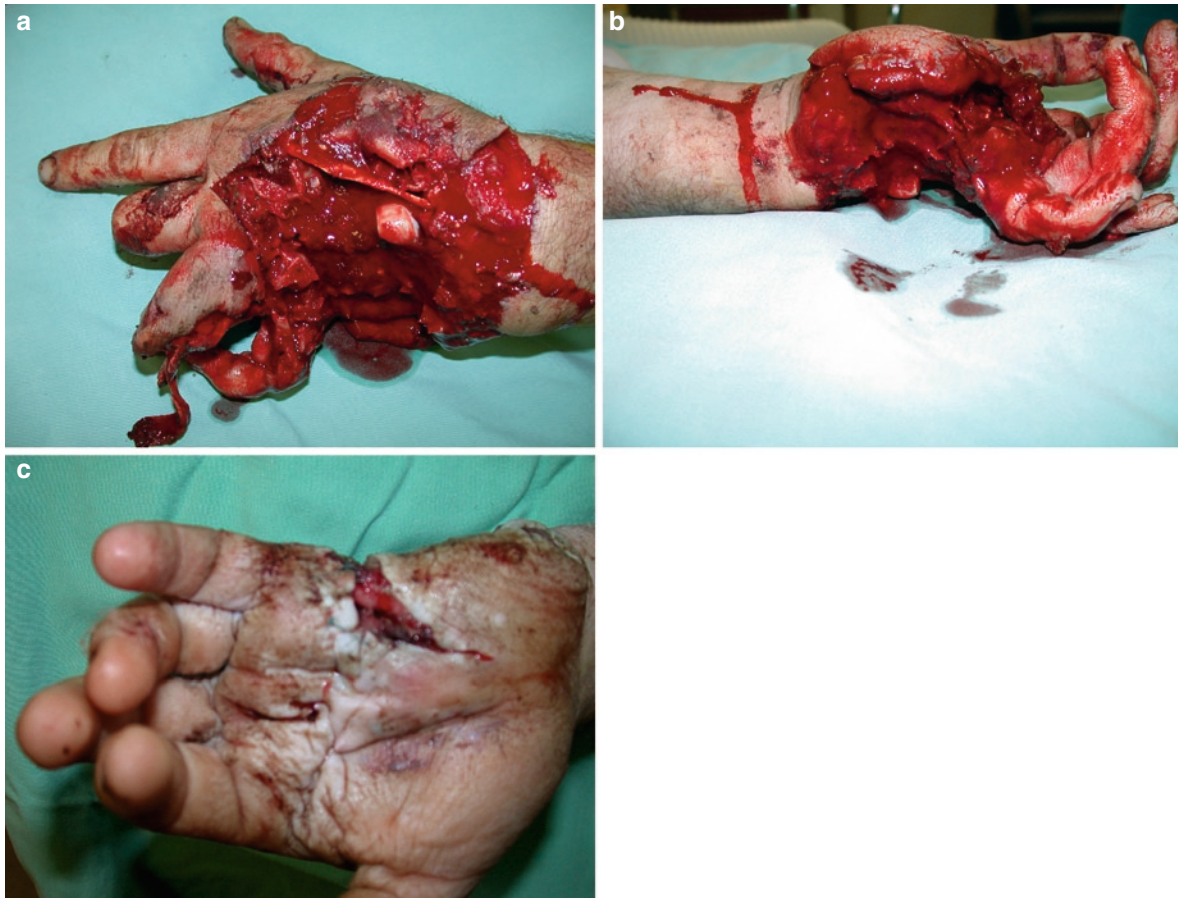

Fig. 16.9 (**a**–**c**) A hand mangled by direct missile injury, salvaged by primary damage control including debridment and bony stabilization, followed by definitive coverage and rehabilitation. The decision of whether to amputate a mangled hand is often challenging. However, the use of mangled extremity scoring system should not supplant the surgeon's clinical judgment

when irreparable vascular injury is present, or when the sum of tissue losses is such as to pose no chance of useful future function, and retention of the finger will impede functional restoration of residual tissues. Whenever possible, the finger should be filleted out to preserve as much skin as possible to cover palmar or dorsal defects [13] (Fig. 16.10a–e).

The wounds are left open and the hand is dressed with a nonadherent layer and gauze. The forearm and hand are splinted in the position of function. Postoperatively, the hand is elevated and antibiotics are continued. Dressings are not routinely changed until delayed primary surgery is performed. Dressings are open only in unexplained increasing pain, continual staining, or odorous draining.

16.5 Delayed Primary and Secondary Surgical Management

16.5.1 Wound Closure: General Principles

War wounds of the hand should not be primarily closed. The full extent of tissue damage cannot be assessed at the primary treatment phase. Wound secretion, edema fluids, retained foreign bodies, and retained nonviable tissues require free drainage. Clean wounds that allow closure are usually attained between the fourth and seventh days. Wound closure is desirable at this stage to cover exposed tendons, fascia, and bone. Exposed tendons and fascia tend to necrosis after the

Fig. 16.10 (**a**–**e**) Complex missile injury of the hand. The middle finger was amputated since it was irreparable; skin was employed to cover the wound. Kirschner wires provided an instant and simple fixation modality

fourth day. Having decided to close the wound where skin loss prevents primary delayed closure, a split skin graft must be considered. At the time of wound closure, definitive treatment is also provided to fractures. Nerve and tendon repair procedures are best delayed until sound and healing has been present for 8–12 weeks. Whenever wound closure creates dead space, delicate drains should be left in for several days.

16.5.2 Principles of Skin Cover

Skin cover in the hand is intended to achieve wound healing as rapidly as possible, to have a high-quality sensation in the skin covering all important tactile and prehensile surfaces, and to cover successfully all vital structures such as tendons and bones. Wound coverage may be achieved by split-thickness skin grafts, vacuum-assisted closure (VAC) therapy, local flaps, distant flaps, neurovascular island flaps, myocutaneous flaps, and free flaps. Defects covered by healthy granulation are satisfactorily covered by split-thickness skin graft. This modality does not provide good coverage for exposed tendons, bone, and joints. In such cases, a flap tissue is required.

The management of extremity injuries on the modern battlefield presents many unique and demanding challenges to reconstructive surgeons, especially in cases with limited potential donor sites for definitive wound coverage. The importance of well-vascularized tissue coverage in complex upper extremity wounds is paramount; this includes free and pedicled flaps tailored to each individual case [11]. Free flap coverage of complex upper extremity defects has important advantages, including avoiding tissue sacrifice from the extremity already functionally compromised by injury, and can cover a larger area with durable, well-vascularized tissue than local or regional flaps [12]. The use of pedicled distant flaps has two advantages: their vascular supplies are obtained outside the zone of trauma and they do not require microscopic anastomosis [11]. Pedicled distant flaps from the trunk include abdominal and groin region flaps. These flaps are used selectively when free flap donor sites are not available (lower extremity amputations or blast injury) or the overall patient condition requires shorter operative times [7].

16.5.3 Management of Bone Injury

Despite appropriate early management, few severe hand injuries will suffer from significant articular bone loss, hand dysfunction, or posttraumatic arthritis. In these situations, arthrodesis remains a mainstay of treatment. Fusion is accomplished in the standard fashion. At the metacarpophalangeal joints of the fingers, excisional or replacement arthroplasty should be considered.

Deformities due to malunion result in substantial loss of function. Operative correction applying compression fixation is the treatment of choice [9].

16.5.4 Management of Nerve Injuries

As war wounds are always contaminated and the nerve injury always includes tearing or crushing, primary or delayed primary nerve repair is usually not appropriate. Secondary nerve repair at 8–12 weeks after skin healing is recommended. Nerve ends that have been tacked together previously are easy to find, and the edges are refreshed and resutured. When gaps exist, which cannot be overcome by mobilization of the nerve ends or by joint positioning, nerve grafting is indicated. Potential donors include the sural nerve, lateral cutaneous nerve of the thigh, saphenous nerve, or the lateral and medial cutaneous nerves of the forearm. Bone shortening may allow end-to-end suture, provided that the shortening does not do further functional damage. Nerve conduits as substitute for autogenous nerve grafts are occasionally used. Digital nerve repair by autogenous vein graft performed at an early stage has also been reported [19].

Painful neuroma is a cause of major hand disability. Management of posttraumatic neuroma begins with nonsurgical techniques such as mechanical desensitization, ultrasound, and electrical nerve stimulation. Surgery is considered only if these do not

provide adequate relief. Surgery includes resection, relocation, imbedding into muscle, or bone or nerve capping [21].

16.5.5 Management of Tendon Injury

Delayed primary tendon can be considered when the injury to the tendon is not of a crushing or lacerating type; even then, tenolysis will be required later in most cases. Extensor tendons should be repaired as a delayed primary procedure whenever possible. Crushed, avulsed, or shredded tendons are best excised to make place for the future secondary grafting procedures. This modality may necessitate the placement of polymeric silicone rods in the first stage to act as a spacer and to prepare for a new tendon bed when severe tissue damage with scarring has occurred. Reconstruction of the pulley system is carried out at this stage. Tendon grafting or transfers are performed at the late second stage. Only fingers with adequate circulation, protective skin coverage, proper bony alignment, and good passive range of joint motion are candidates for secondary two-stage tendon reconstruction. Arthrodesis may be a proper alternative to tendon graft or transfer in the reconstruction of the hand.

Patients with tendon adherence and loss of active range of motion despite a long rehabilitation program are considered for tenolysis. The procedure is technically demanding. Preoperative details of previous operations, postoperative treatment, patient's motivation, and occupational needs must be taken into account prior to surgery [4, 9].

16.5.6 Amputation

Secondary amputation is performed if adequate circulation is not realized or if uncontrollable infection exists. Late amputation is required if the finger is painful, stiff, useless, or interferes with the functioning of the other fingers. The loss of an isolated finger, except the thumb, is well tolerated; however, amputation of multiple fingers significantly compromises the hand functioning. Maintaining or reconstructing at least the thumb and one opposing digit is a minimal requirement for hand functioning.

16.6 Physiotherapy, Occupational Therapy, and Early Motion

Physical and occupational therapists play a critical role in evaluating, encouraging, instructing, and accompanying the injured in the long rehabilitative course. Wound care is very important at the early stage and includes whirlpool, debridement, dressing changes, wound status monitoring, and pin care. Chronic swelling is one of the main causes of stiffness due to lack of active muscle function and immobilization of joints leading to joint capsule and ligament contractures. Various modalities are applied to control edema, such as elevation, exercises, compression garments, retrograde massage, cold compresses, and contrast baths. Early motion prevents swelling. Motion is also psychologically important, since it persuades the injured that functional recovery is attainable. External splinting or fixation of fractures, and primary or delayed primary tendon and nerve repair militate against early motion. This is an additional reason to avoid tendon and nerve repair in the critical early phase when motion (at least passive) is key. Internal stabilization of fractures is greatly advantageous in this respect. Reducing pain is mandatory, since pain interferes with early motion. Neuropathic pain is associated with blast injuries with nerve involvement. It can threaten the outcome of any intervention, and may evolve to a complex regional pain syndrome (CRPS). Skilled pain management is required.

Custom-made thermoplastic static and dynamic splints are made to protect injured structures, to decrease pain, to mobilize stiff joint, and to enhance upper extremity function. An appropriate and individualized rehabilitation program helps the injured to resume the activities they are missing because of the injury.

16.7 The Hidden Injury: Psychosocial Implications of Hand Injuries

In addition to the motor function of the upper limb, the hand is also a sensory organ, supplementing the visual, auditory, and olfactory inputs. Mutilating hand injuries may produce severe psychological and emotional sequelae [8]. Restoration of hand function and

appearance is a crucial part in the social rehabilitation of the patient and his self-image perception. These psychosocial consequences should be addressed concurrently with functional rehabilitation [14]. Patients must also learn to live with the residual problems that cannot be made better.

References

1. Burgess, A.R., Poka, A., Brumback, R.J., Bosse, M.J.: Management of op en grade III tibial fractures. Orthop. Clin. North Am. **18**, 85–93 (1987)
2. Carter, P.R.: The embryogenesis of the specialty of Hand Surgery: a story of three great Americans-a politician, a general and a duck hunter: the 2002 Richard J. Smith Memorial Lecture. J. Hand Surg. **28A**, 185–198 (2003)
3. Eardley, W.G., Stewart, P.M.: Early management of ballistic hand trauma. J. Am. Acad. Orthop. Surg. **18**, 118–126 (2010)
4. Feldscher, S.R., Schneider, L.H.: Flexor tenolysis. Hand Surg. **7**, 61–74 (2002)
5. Freeland, A.E., Lineaweaver, W.C., Lindly, S.G.: Fracture fixation in the multilated hand. Hand Clin. **19**, 51–61 (2003)
6. Greer, M.A., Miklos-Essenberg, M.E., Harrison-Weaver, S.: A review of 41 upper extremity war injuries and the protective gear worn during Operation Enduring Freedom and Operation Iraqi Freedom. Mil. Med. **171**, 595–597 (2006)
7. Groner, J.P., Weeks, P.M.: Skin and soft tissue replacement in the hand. In: Smith, J.W., Aston, S.J. (eds.) Plastic Surgery, pp. 874–891. Little, Brown & Company, Boston, MA (1991)
8. Grunert, B.K., Smith, C.J., Devine, C.A., et al.: Early psychological aspect of severe hand injury. J. Hand Surg. **13B**, 177–180 (1988)
9. Jupiter, J.B., Goldfarb, C.A., Nagy, L., Boyer, M.I.: Posttraumatic reconstruction in the hand. J. Bone Joint Surg. **89A**, 428–435 (2007)
10. Kenesi, C., Masmejean, E.: Emergency treatment of hand trauma in France, an important public health challenge. Bull. Acad. Natl Méd. **188**, 793–801 (2004) [French]
11. Kumar, A.R., Grewal, N.S., Chung, T.L., Bradley, J.P.: Lessons from the modern battlefield: successful upper extremity injury reconstruction in the subacute period. J. Trauma **67**, 752–757 (2009)
12. Lohman, R.F., Nabawi, A.S., Reece, G.P., et al.: Soft tissue sarcoma of the upper extremity: a 5-year experience at two institutions emphasizing the role of soft tissue flap reconstruction. Cancer **94**, 2256–2264 (2002)
13. McCormick, R.M.: Reconstructive surgery and the immediate care of the severely injured hand. Clin. Orthop. **13**, 75 (1959)
14. Meyer, T.M.: Psychological aspects of mutilating hand injuries. Hand Clin. **19**, 41–49 (2003)
15. Omer Jr., G.E.: Development of hand surgery: education of hand surgeons. J. Hand Surg. **25A**, 616–628 (2000)
16. Rowley, D.I.: The management of war wounds involving bone. J. Bone Joint Surg. **78B**, 706–709 (1996)
17. Skov, O., Jeune, B., Lauritsen, J.M., Barfred, T.: Occupational hand injuries. A population based description of the incidence and referral to casualty departments. Ugeskr. Laeger **161**, 3285–3288 (1999) [Danish]
18. Stahl, S., Lerner, A., Kaufman, T.: Immediate autografting of bone in open fractures with bone loss of the hand: a preliminary report. Case reports. Scand. J. Plast. Reconstr. Surg. Hand Surg. **33**, 117–122 (1999)
19. Stahl, S., Rosenberg, N.: Digital nerve repair by autogenous vein graft in high-velocity gunshot wounds. Mil. Med. **164**, 603–604 (1999)
20. Wangensteen, O.H., Wangensteen, S.D., Klinger, C.F.: Wound management of Ambroise Pare and Dominique Larrey, great French military surgeons of the 16th and 19th centuries. Bull. Hist. Med. **46**, 207–234 (1972)
21. Watson, J., Gonzalez, M., Romero, A., Kerns, J.: Neuroma of the hand and upper extremity. J. Hand Surg. **35**, 499–510 (2010)