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Diagnosis And Management Of Hand Injuries In The ED

It's a busy Friday night in your ED, and you evaluate a 21-year-old male who has lacerated his flexor tendon on a glass bottle during a bar fight. The on-call orthopedist suggests placing Steri-Strips™ and sending the patient to his clinic early next week. After hanging up the phone, you immediately have misgivings. The other orthopedists usually take the patient to the operating room directly from the ED. You ask yourself, "Should I start antibiotics? Did he really understand me in his post-REM sleep fog? Shouldn't the patient get his tendon repaired tonight, or at least this weekend? How do I splint the finger?" You wonder if you shouldn't call him back, just to be sure....

THE hand is a complex and truly amazing work of anatomy. The bones, muscles, tendons, nerves, and ligaments work in precision to create a masterpiece of functionality and sense. Disrupt just one of these parts, and the entire balance of the hand can be thrown off. Yet our patients often seem determined to do exactly that, and the literature is replete with an unusual and comprehensive list of how these injuries occur: axes, dry cleaner injectors, gunshot wounds, farming mishaps, table saws, boxing, rock climbing — the list goes on and on.

The critical importance of our sense of touch makes hand injuries different from other traumatic injuries. We are constantly receiving sensory input from our hands, relying on that information for our normal day-to-day functioning: We grope for the snooze button in the dark, type on a computer, cut, hammer, throw a softball, caress a lover's face or hold a child's hand without conscious effort. When a traumatic hand injury results in chronic stiffness, pain, and dysfunction, a patient will be constantly reminded of it during nearly every waking minute of the day.

An entire subspecialty of training is dedicated to the hand, yet emergency physicians, general orthopedists, and primary care providers manage the bulk of acute, traumatic hand injuries. The art of managing emergent hand conditions rests in correctly identifying and treating such injuries, which can be difficult at times, due to subtle presentations. A critical step is determining which ones you can appropriately manage, and which need ur-

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CME Objectives

Upon completing this article, you should be able to:

1. Apply basic knowledge of hand anatomy and physiology while examining and managing acute hand injuries;
2. Classify common hand fractures, dislocations, and tendon injuries and their complications;
3. Identify the steps in properly evaluating open hand wounds, considering high-risk situations that require special attention; and
4. Discuss the proper ED management of hand burns, arterial and nerve injury, and high-pressure injection injury to the hand.

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gent referral, then providing proper splinting and wound management. This issue of *Emergency Medicine PRACTICE* will provide guidelines that the emergency physician can use to meet these goals.

Critical Appraisal Of The Literature

Overall, the hand injury literature is not evidence-based, but instead relies on tradition. A search of both the National Guideline Clearinghouse (http://www.guidelines.gov) and OVID found only 3 evidence-based practice guidelines related to the evaluation and management of hand injuries. These include recommendations for hand imaging by an expert panel of radiologists, a clinical policy on the approach to penetrating extremity trauma by the American College of Emergency Physicians, and a Cochrane systematic review of antibiotic prophylaxis for mammalian bites, all of which are referenced in more detail later in this article. The stronger randomized, controlled studies that exist on hand injuries focus on their operative or rehabilitative aspects and are found in the hand surgery or occupational therapy literature. Even in respected texts on hand surgery, several authors disagree over how to best evaluate and treat a given injury. Emergency medicine-based trials are sparse regarding the ED management of hand injuries, leaving us to rely primarily on "expert opinion." Recommendations for managing injuries pending specialty consultation (which can be delayed for days or weeks) lack support, and in many instances simply do not exist. Regarding operative management, enough variation in surgical practice exists that makes it wise to refer early and leave definitive decisions to the consultant.

Most practicing emergency physicians have been taught and use sound and reasonable approaches to evaluating hand injuries. Most of these pass "the common sense test" and, until more definitive literature exists, should be considered useful. Expert witnesses most certainly will refer to such recommendations and hold them up as "standard of care," even if they simply come from textbooks and are not clearly supported by definitive data. Hopefully, with time, we will fill in the knowledge gaps with evidence-based support, but much work remains.

Epidemiology

Hand injuries comprise up to 10% of ED visits and range from simple lacerations or finger sprains to mutilating injuries or amputations.[1,2] Hand lacerations are the most frequently seen injuries of the hand, yet hand fractures and dislocations account for approximately 20% of fractures in general.[3,4] The type of injury seen in each decade of life varies; children most commonly are injured at home, with fingertip injuries and burns prevailing.[5] In 1 study, over half of abused infants had hand fractures — a subtle but important fact to keep in mind when evaluating these injuries in this age group.[6] Falls are frequently the etiology in the elderly; sports in younger patients, and work-related injuries in middle-aged individuals.[7] Males are injured more frequently in almost all age groups.[5,8] More severe trauma usually results from motor vehicle collisions, farm or industrial machinery, table saws, fireworks, snowblowers, or lawnmowers. These are generally "no-brainers" that require prompt involvement by a hand surgeon.

Fingers are fractured more frequently than metacarpals, with the little finger ray (phalanx and metacarpal) being fractured more often than the other 4 rays.[4] A British study published in 1990 pointed out that 25% of finger fractures were initially mismanaged, leading the authors to recommend that all such injuries be referred to a hand surgeon; a corollary to this study is the imperative that emergency physicians be facile in recognizing and managing hand injuries.[9]

Missed tendon lacerations are a common cause for litigation, thus driving the need for all emergency physicians to have a basic understanding of the anatomical and functional complexity of hand anatomy. The expense of treating a patient combined with their time lost from workplace productivity may exceed tens of thousands of dollars, as most patients rely heavily on their hands to function optimally on the job.[10]

Anatomy And Physiology Of The Hand

No other musculoskeletal system is as multifaceted and complex as the hand, making it impractical for most to memorize and fully understand all the details of hand anatomy and physiology. However, the practicing emergency physician should "have a feel" for the general function of the bones, tendons, joints, vascular supply, and nerves of the hand. Familiarization with these basic tenets makes it possible to identify injuries and recognize both their potential short- and long-term complications.

General Terms

It is best to describe the surfaces of the hand using proper anatomic terminology; not only is it more descriptive, but it will lend credence to conversations with your consultants. The palmar or volar surface is opposite the dorsal surface of the hand, while the surface of each finger or hand that is facing the radius is termed the radial surface. Conversely, the ulnar surface lies on the same side of the ulna in that extremity. Motion of joints is described as flexion, extension, hyperextension, radial deviation, or ulnar deviation. The type of deviation is determined by the direction of the most distal part involved. The fingers, or phalanges, are aptly named index, middle (or long), ring, and little. Each finger has 2 interphalangeal (IP) joints — distal (DIP) and proximal (PIP) — while the thumb has 1 IP joint. The 5 metacarpophalangeal (MP) joints connect the metacarpal (MC) bones to the proximal phalanges. The metacarpals are similarly named as the phalanges, or they may be referred to as MC 1 (thumb) through MC 5 (little finger).

Skeleton

There are 19 bones of each hand (14 phalanges and 5 meta-

carpals). The distal carpals of the wrist, along with the index and middle finger metacarpal, form the fixed and immobile center of the hand.

Blood Supply

A series of arches and arcades provide dual blood supply to the entire hand and all digits. The radial and ulnar arteries provide the major blood supply to the hand by forming the superficial and deep palmar arches. The common digital arteries are the main branches off the superficial arch, and there are many variations of its branches. The proper digital arteries have multiple transverse arcades of branches in the digits. This system of abundant collaterals in the hand makes it very unlikely that you will encounter clinical problems with disruption of 1 of the 2 main arteries at the wrist or with disruption of a palmar arch.[11] Veins generally parallel the deep arterial system.

Synovial Spaces

Synovial fluid provides nourishment to tendons and decreases friction during tendon movement. Extensor tendons have increased resistance to infection because they do not lie within fixed sheaths in the hand, although small sheaths do surround them at the wrist. Flexor tendon sheaths can act as a pathway for the spread of infection (flexor tenosynovitis), most often from penetrating trauma.

Figure 1. The flexor digitorum profundus.

The flexor digitorum profundus passes through the tails of the flexor digitorm superficialis on the way to its insertion into the distal phalanx.

Used with permission from: Green DP, Hotchkiss RN, Pederson WC, eds. *Operative Hand Surgery*. Vol 1. New York: Churchill Livingstone; 1999:1899. Figure 60-1.

Flexor Tendons

The 9 flexor tendons cross the wrist volarly. The thumb has only 1 flexor tendon, the flexor pollicis longus, which distinguishes it from the other digits. The remaining digits have 2 flexor tendons, the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP). At the base of each proximal phalanx, the FDS bifurcates into 2 slips, allowing the FDP to emerge to a superficial position between the 2 slips (**Figure 1**). The 2 FDS slips insert at the proximal aspect of the middle phalanx, while the FDP inserts at the base of the distal phalanx. Distal to the MP joint, both flexor tendons become enclosed in a fibrous synovial sheath. Regions of thickening form pulleys that prevent bowstringing of the flexor tendons as they cross joints, thus facilitating smooth and efficient flexion. These pulleys are often injured acutely or chronically in the hands of rock climbers, leading to "bowstringing" of the flexor tendon.[12]

Extensor Tendons

The 9 extensor tendons of the hand cross the wrist dorsally and are separated into 6 distinct compartments while passing under the extensor retinaculum. This is the only area where they are encompassed in synovial sheaths. The retinaculum and compartment roofs provide stabilization for the extensor tendons, thus preventing bowstringing of the tendons in extension.

Each extensor mechanism is a complex arrangement of muscle tendon units of the long extensor tendons and the intrinsic system. Because of this complex anatomy, injuries involving the extensor mechanism require meticulous repair.

Prehospital Care

Prehospital care focuses on stabilization of the injury, on hemorrhage and pain control, as well as on the care of amputated parts. The injured extremity should be immobilized and elevated. Hemorrhage control can typically be achieved with direct pressure. In rare instances, patients suffer arterial injuries that can often be difficult to control with direct pressure. Tourniquet use is appropriate to prevent exsanguination or shock when direct pressure of the radial or ulnar artery is unsuccessful. A manual blood pressure cuff applied proximal to the injury and inflated to 250 mm Hg will provide adequate hemostasis during prehospital transport. Prehospital care personnel should use intravenous narcotics for pain relief and anxiolytics when indicated, such as with crush or mangling injuries.

Amputations

Limited research has been done on the care of an amputated digit or hand. Paramedics should try to find *any* amputated digit, wrap it in sterile, saline-soaked gauze,

Table 1. Indications For Digital Replantation.

Single digit amputation between the PIP and DIP
Amputated thumbs
Multiple digit amputations
Any amputation in a child
Mid-palmar amputations

then place it into a plastic bag that is in turn placed into a separate plastic bag containing ice. Cooling an amputated digit close to 40° F will enhance survival; 1 hour of warm ischemia is approximately equal to 6 hours of cold ischemia.[13] Even if the amputated part is not suitable for replantation, it may used as a source of donor vessels, skin, or bone. Recommendations for digit replantation are presented in **Table 1**.

ED Evaluation

First and foremost, address the ABCs in any acute traumatic scenario. A mangled, amputated, or crushed hand should not draw attention away from more serious life threats and, unless profusely bleeding, should not take priority in the multitrauma patient.

History

Always obtain a complete history when evaluating patients with hand injuries. EMS personnel or bystanders may be able to offer important historical facts, if the patient is unable to communicate. Was the patient's hand protruding through the window when a vehicle rolled? Were there any gross deformities that were reduced prior to transport? Basic historical details should include: patient's hand dominance, medical history (especially immunocompromising diseases or medications), tetanus status, allergies, smoking status, previous hand injuries or dysfunction, and occupation and hobbies (eg, musician or anything requiring fine motor control). Obtain a history of the mechanism of injury. Crush injuries impart more force and damage to soft tissue than simple blows to the hand, increasing the risk of compartment syndrome and wound infection. Identify the force causing a joint dislocation and in which direction the joint was deformed, if already reduced: This helps diagnosing ligament damage in closed injuries.

Seek details surrounding lacerations or puncture wounds. Did the patient fall on a road covered with gravel? Did glass, tree branches or other material cause the laceration? Causes such as these not only raise the suspicion of foreign bodies in the wound, but also direct the type of imaging used to evaluate the wound for foreign bodies. In a study addressing the question of retained glass, foreign body sensation was a poor predictor of glass foreign body (positive predictive value of only 31%). In one study, patients who thought that there was no glass in the wound were usually right, but there were still a good number of false negatives (negative predictive value of 89%).[14]

Time since injury may help determine whether or not a wound should be closed and the risk for infection. Exposure to contamination (eg, lake water, soil, "dirty" tool or knife, or bites) may also influence clinical decisions involving closure and antibiotic therapy. Determine the position of the hand at the time of injury; this can help locate damaged structures during physical examination that are not visualized in a wound of a hand in the resting position. Pay particular attention to open injuries of the MP joints. Ruling out a "fight-bite" injury (striking of the knuckles against teeth) as the etiology is imperative, as these wounds require a higher level of management than most other hand lacerations.

Examination

While providing basic trauma care, obtain hemorrhage control of an open wound or amputation by using direct pressure with gauze and arm/hand elevation. If this fails, as it rarely should, the next step is to place a blood pressure cuff at the distal forearm or wrist. Inflate to 250 mm Hg pressure for 20- to 30-minute periods. Most patients tolerate tourniquets of this duration without significant pain.[15] Avoid using a Kelly clamp and thereby crushing arteries and nearby nerves. Make all efforts to control hemorrhage in a way that will not interfere with subsequent vascular repair by the hand surgeon, including prolonged tourniquet times. While there are conflicting recommendations in the literature regarding safety and length of tourniquet time during hand surgery, 2 hours is the most widely accepted figure.[16] Nerve and muscle injury may result from prolonged ischemia, but reperfusion ("breather") breaks of 5-10 minutes may help if a tourniquet is in place for more than 30 minutes.[17] The Allen test can ensure patency of the ulnar and radial arteries and palmar arches. Perform the Allen test by having the patient clench their fist tightly. Occlude the radial and ulnar arteries and ask the patient to open the blanched hand. Release pressure over one of the arteries and note how long it takes for color to return. If the artery and collaterals are patent, this should occur in 3-5 seconds. Repeat the test in a similar fashion to evaluate the patency of the other artery.

Remove all rings (edema often involves even uninjured fingers) and clean gross blood and debris off the injured hand. Systematically examine the hand, beginning with an overall assessment of the position of the hand and fingers. Note pallor, gross deformity, or phalanges lying in abnormal positions compared to the others. Palpate all bones of the hand and wrist and ensure full range of motion of all joints, noting any tenderness, crepitus, or laxity. Discoloration, edema, and tenderness over a joint may indicate a closed ligament, joint capsule, or tendon injury. Examine the entire hand, since focusing only on apparent injuries may lead to missing the less obvious ones. Deter-

Figure 2. Median nerve test.

In this figure, thumb abduction strength is being checked in a patient whose palm is lying flat while lifting the thumb towards the ceiling. This assesses the abductor pollicus brevis muscle (supplied by a median nerve branch).

mine if any joint capsules are penetrated, which would be an indication for irrigation in the operating room.

Next, assess the sensation and motor strength in the hand to identify nerve injury. The median, radial, and ulnar nerves provide sensation to the hand. Test for sensation of the median nerve at the palmar tip of the index finger, the ulnar nerve at the palmar surface of the little finger, and the radial nerve at the dorsal surface of the web space between the thumb and index finger. Comparative 2-point discrimination is the most accurate assessment of sensation. Intact digital nerves should be able to distinguish points 2-5 mm apart at the fingertips and 7-12 mm at the base of the palm,[18] but this distance may increase with age.[19] When in doubt, compare the injured area with the uninjured hand. While testing sensation, recall that individual digital nerves supply one side of each digit. Lightly stroke ECG calipers, 2 sharp edges of a broken tongue blade, or a bent paper clip in a linear (not transverse) fashion along the palmar surface of the finger to test for this. Loss of sweating distal to the site of injury indicates nerve laceration, as does failure of normal wrinkling of the skin, after soaking the digit of concern in warm water for 30 minutes.[20]

The median and ulnar nerves provide the entire motor function of the hand (the radial nerve primarily innervates the wrist extensors, and radial nerve injury at the hand should not adversely affect this). Palpate the contracting muscle belly of an injured hand, rather than simply observing it for movement. See **Figure 2** for assessment of the median nerve function. Testing the median nerve motor function by pinching the small finger and thumb together can give false negatives with ulnar nerve injury and should not be used.[21] Ulnar nerve motor function is tested as shown in **Figure 3**.

Once the neurologic examination has been noted, anesthetize any open wounds prior to exploration (see subsequent section on anesthetic techniques). Failure to provide adequate exposure of deeper wound structures because of patient discomfort often leads to missed injuries. Proper lighting is vital; a portable headlight or overhead direct beam is optimal. Examining a hand in a poorly lighted hall or exam room gives a false sense of reassurance. (*Yes, we've all done it before when the rooms are full in the ED!*) A bloodless field is needed to properly evaluate all but the most superficial hand wounds. Milk the hand or finger with 4X4 sterile gauzes to remove the venous blood after placing a tourniquet. Position a forearm or wrist blood pressure tourniquet as described above, or use a finger tourniquet.[22] Excessive pressures in elastic finger tourniquets may be generated, resulting in nerve injury, so use them for shorter time periods (< 1 hour) and do not forget to remove them after finishing the procedure to prevent serious complications![16]

To check for tendon injuries, first assess the hand in a resting position. Since flexor and extensor tendons pull the fingers in opposite directions, complete disruption of

Figure 3. Ulnar nerve tests.

The first image depicts palpation of contraction of the first dorsal interosseous, which verifies ulnar nerve strength. The second image shows Froment's test; the thumb IP flexion on the right indicates compensation for adductor pollicis weakness due to ulnar nerve palsy (positive Froment's sign).

either one may result in the finger resting in a flexed or extended stance in relation to the other fingers. Realize that nearly complete disruption is needed to lose function of an injured tendon. Partial tendon injuries tend to cause more pain than expected in a wound when that tendon is flexed or extended against resistance. Move the hand and fingers through a full range of motion, particularly back to the hand position at the time of injury, to expose tendon injuries that have retracted out of sight from the open wound. Ask the patient to extend the finger against resistance to check for extensor tendon function. Check flexor tendon function as shown in **Figure 4**. If the FDS is severed, the patient is unable to flex the PIP; however, the PIP may flex if the FDP is intact and the uninvolved fingers are not held in extension. This is why it is imperative to test both the FDS and FDP separately.

Document any angulation or rotational deformities of the fingers as shown in **Figure 5**.

Radiology

There are no prospective data analyzing specific historical or examination factors that should trigger a provider to or-

Figure 4. Tests of tendon function.

In the first image, the examiner tests FDP tendon function by holding the PIP in extension. In the second image, the examiner tests the FDS by holding the uninvolved fingers flat, while having the patient flex the PIP of the injured finger.

Figure 5. Malrotation assessment.

In the first image, all fingers point toward the flexor carpi radialis (visible at the mid volar wrist crease) with normal rotational alignment. However, soft-tissue swelling at the fifth MC may cause apparent malrotation of the little finger ("pseudorotation") with this method. A more accurate method to check for malrotation, shown in the second image, may be to assess nail plate alignment with gentle flexion of the fingers. Note that all nail plates lie in the same plane.

der hand radiographs. Despite large discrepancies in clinical suspicion and radiological confirmation of fractures,[24] most practitioners order films on patients with significant point tenderness or other external signs of trauma. The American College of Radiology (ACR), Expert Panel on Musculoskeletal Imaging reviewed the current literature on hand imaging and made the following recommendations in 2001:[25]

1. For suspected metacarpal fracture or dislocation: PA, lateral, and semipronated oblique (off-lateral) view are most appropriate and should be a part of a standard hand series. CT is indicated for patients with equivocal plain films or negative hand series but a strong clinical concern.
2. For suspected phalangeal fractures or dislocations: PA (entire hand or finger only), lateral, and externally rotated oblique are most appropriate and should be obtained. An internally rotated oblique may be appropriate, but does not need to be routinely ordered.
3. For suspected thumb fractures or dislocations: PA or AP of thumb, lateral, PA of entire hand or internally rotated oblique of the thumb are indicated.

CT scanning is recommended for assessment of fracture-dislocations of the carpometacarpal joints and is, in general, more accurate in diagnosing and evaluating bony structures of the hand. Use it when additional radiographic views still do not identify or delineate fractures adequately. The use of ultrasonography in long bone fractures has been advocated, but there are currently no solid prospective data for its use in diagnosing hand or finger fractures. MRI, while indicated for further evaluation of suspected carpal and distal radial injuries, is not recommended in the ACR Appropriateness Criteria for metacarpal and hand fractures. When evaluating suspected gamekeeper injuries, however, MRI is recommended and is more appropriate than stress views, US, or arthrography. Other radiographic modalities for specific injuries will be discussed in subsequent sections here.

ED Management

Anesthesia

As previously stated, providing adequate anesthesia early in the evaluation of hand injuries facilitates full wound exploration. Direct injection of local anesthetics into finger wounds is an option, but this tends to be more painful and less effective than a digital block.[26] (For small lacerations, however, direct injection may be useful and less painful.) Wrist anesthesia should also be less painful than direct infiltration, although no studies directly compare the 2 methods prospectively. When anesthetizing fingers, digital block anesthesia is more efficacious with quicker onset of anesthesia than metacarpal block, but both seem equally painful.[27] Slow injection using an appropriately sized needle (27-gauge) and a 5 cc syringe should help lessen the pain.

When anesthetizing an injured finger, digital block using lidocaine buffered with sodium bicarbonate (1 part bicarbonate to 9 parts lidocaine) is less painful upon injection, yet is as effective as plain lidocaine.[28] Lidocaine with epinephrine lasts longer than plain lidocaine, decreasing the need for repeat injections, and it provides a less bloody field. Bupivacaine can also be buffered with bicarbonate (1:200), has a longer half-life than lidocaine, and is the authors' preferred anesthetic in conjunction with a digit tourniquet for open injuries.

A common misconception is that epinephrine should not be used with local anesthetics when performing digital blocks. Several review articles have touted its safety, however, and there have been no case reports of digital gangrene using commercial lidocaine with epinephrine.[29-31] Multiple studies involving thousands of patients support its safety profile, and the decreased digital blood flow has been shown to be temporary, with perfusion being maintained without intervention.[31-35] Most cases of digital gangrene involving epinephrine included other conditions that may have contributed to the complication (large volumes or circumferential injections, hot soaks, tight tourniquets, infection, and unknown or higher epinephrine concentrations based on manual dilution).[29] Keep in mind that tourniquet use itself can cause iatrogenic neuropathy. It may also play a role in digital gangrene and necrosis and has not necessarily been proven to be a safer practice than using lower concentrations of epinephrine in digital block anesthetics. Most epinephrine-containing anesthetics used in the ED are 1:100,000 concentration, and lower concentrations such as this have been safely used for digital block. Key points to follow when using digital blocks include:

1. Small amounts of local anesthetics with dilute epinephrine (1:100,00–1:200,000) are probably safe for digital infiltration or blocks.
2. Do not do a circumferential block of the digits.
3. Use small needles to avoid injuring the vessels.
4. Avoid postoperative hot soaks.
5. Buffer the anesthetic.
6. Bandages should not be constrictive or excessively tight.
7. Avoid using epinephrine in patients with vasospastic, thrombotic, or extreme medical conditions.[29]

To perform a digital block, insert a 27-gauge needle at the dorsal skin of the affected digit, just distal to the MP joint, and raise a small wheal of anesthetic. Direct the needle in a palmar direction and near the edge of the bone of the proximal phalynx, until the needle tip is near the palm. Aspirate to check for blood, withdraw the needle several millimeters, then slowly inject 0.5–1.0 ml of anesthetic. Without completely withdrawing the needle, redirect it across the dorsum of the proximal finger and deposit another 0.5–1.0 ml of anesthetic. Take care not to inject more than 2-3 ml of anesthetic in the adult and use an appropriately smaller volume in children, depending on their size. Large volumes of anesthetic deposited in a circumferential fashion can cause finger ischemia and necrosis.

Figure 6. Median wrist block.

Insert the needle between the flexor carpi radialis and palmaris longus tendons, depositing 5 mL of anesthetic where the nerve passes just beneath the retinaculum.

Figure 7. Ulnar wrist block.

This photo depicts the lateral approach as the needle is passed dorsal to the flexor carpi ulnaris tendon for 1.0-1.5 cm. Once parasthesias are elicited, 5 mL of anesthetic is deposited.

Wrist blocks are less commonly used by emergency physicians, but they are helpful when a wound is more proximal to the fingers. Block the median nerve at the proximal wrist crease as it passes between the flexor carpi radialis (FCR) and, if present, the palmaris longis. (See **Figure 6**.) Deposit 5 ml of anesthetic underneath the retinaculum, after passing a 25- or 27-gauge needle just ulnar to the FCR. It may take 20-30 minutes for this to take effect. Ulnar nerve blocks can be approached in one of 2 directions. The ulnar nerve lies within a thick neurovascular bundle at the radial aspect of the flexor carpi ulnaris (FCU) tendon (the thick tendon easily palpable at the ulnar aspect of the wrist when flexed against resistance). The ulnar artery lies next to the nerve, so take care not to inject the artery instead. Insert the needle at the radial border of the FCU at the proximal volar wrist crease and advance 1 to 1.5 cm, until you elicit paresthesias, then deposit 5 ml of anesthetic. For the lateral approach see **Figure 7**. A radial nerve block is accomplished by injecting 5–10 ml of anesthetic at a level just distal to the radial styloid.

A hematoma block is most commonly utilized for reducing metacarpal fractures in the ED and is rather simple to perform. After properly sterilizing the site, insert a 25- or 27-gauge needle into the hematoma at the fracture site. Aspirate blood and then inject 5–10 ml of anesthetic into the site. Anesthesia is generally achieved in 15–20 minutes, but may not be complete. This procedure is commonly used in the ED, yet few studies have directly compared its efficacy and safety to other methods of analgesia for fracture reduction.[36]

Splinting

Hand splints are generally applied for fractures, reduced dislocations, ligamentous or tendon injuries, lacerations, burns, or painful contusions. Many patients hold their hands in the wounded position, with wrist and IPs flexed and MPs extended, and failure to immobilize can lead to a nonfunctional and stiff hand. Splints should be placed to immobilize only the necessary joints and allow free motion in all others.

Two similar positions of hand splinting are most commonly recommended by hand surgeons. The safe position is similar to grasping a round glass, with the wrist extended to 30 degrees, the MPs flexed to 60 degrees and the IPs minimally flexed. (See the first image in **Figure 8**.) The intrinsic plus position differs by having slightly more MP flexion (90 degrees) and fully extended IPs. (Second image in **Figure 8**.) Burkhalter described a method of splinting that uses a volar slab of plaster or fiberglass up to the proximal palmar crease to hold the wrist in extension. The MPs must be able to fully flex to allow for the extensor bands to apply a reducing force for fracture reduction, so do not extend the volar slab past the proximal crease.[8] A dorsally applied slab runs from the forearm to the proximal phalanges, holding the MPs in 90 degrees flexion, but allowing free IP movement, (See **Figure 9** on page 10.)[37] This is a good general splint for contusions, metacarpal and proximal/middle phalangeal fractures, and extensor tendon injuries proximal to the PIP. An ulnar gutter (for ring and little finger and metacarpal) and radial gutter (for index and middle finger/MC) splint requires only one slab and should be applied with similar joint immobilization.

Emergency physicians use various finger splints for sprains, fractures, infections, or contusions. Stable nondisplaced fractures, stable dislocation reductions, and IP sprains are generally appropriate for buddy splinting. This type of simple dynamic splinting utilizes the adjacent finger to stabilize the fracture or ligamentous injury, preventing complications while allowing early mobilization during healing. Several simple extension splints are available to treat mallet injuries, and dorsal foam splints

with aluminum backing can be used to immobilize stable injuries of the PIP, DIP, and middle/distal phalanges. Use thumb spica splints to immobilize thumb fractures and ligamentous injuries of the thumb.

Open Wounds

Several irrigation solutions exist for cleansing hand wounds. Regardless of the solution, copious irrigation of an anesthetized open wound, followed by gentle scrubbing and debridement of devitalized tissue, are essential. Some solutions' bactericidal activity is offset by cellular toxicity, which can result in imperfect wound healing or late infections. These include detergent-containing povidone-iodine ("scrub"), hydrogen peroxide, and chlorhexidine.[38] On the other hand, normal saline, using high pressure and high volume systems, is effective and nontoxic to tissues. Most authors recommend wound irrigation pressures of approximately 0.5 kilogram-force per square centimeter (kgf/cm^2) or 5-10 psi generated by a syringe with an 18-ga angiocath and a minimum of 100 to 300 mL of continuous irrigation.

Irrigation with *tap water* is a relatively effortless and time-saving method of cleansing hand wounds. Theoretically, it may save time, money, and decrease splash risks. In a recent randomized, prospective study of over 500 children with simple lacerations, no significantly different rates of infection (approximately 3%) were found when comparing wounds irrigated with normal saline versus tap water.[39] Physicians evaluating the patients on follow-up were blinded to the irrigation methods. Interestingly, twice as many hand wounds, which are generally believed to be more infection prone, were randomized to the tap water group. Tap water pressures generated in this study were about 3-4 kgf/cm^2, which are fairly representative of most sinks' tap water pressures and higher than some normal saline irrigation systems. The limited evidence suggests that this technique may be efficacious and especially practical for cleansing hand wounds.

Cleansing hand wounds with *povidone-iodine solution* (Betadine®) is a controversial subject with conflicting evidence. Higher concentrations have proven to be tissue-toxic, but there are no studies specifically assessing hand wounds to confirm these findings. In one study, there was no significant difference in infection rates between wounds irrigated with 1% povidone-iodine and normal saline.[40] In another prospective trial, sutured hand lacerations treated with povidone-iodine dry powder aerosol spray vs control had similarly low infection rates, side effects, and imperfect healing rates.[41] Soaking of wounds in any solution appears ineffective in decreasing bacterial counts. The use of povidone-iodine solutions greater than 1% should be avoided.[42] There are no studies of hand wounds showing that any solution or method is significantly more efficacious than high-pressure, normal saline irrigation.

Figure 8. Recommended splinting positions.

The first image shows the "safe" position of the hand; the second image depicts the intrinsic plus position.

Foreign Bodies

Hand wounds are notorious for harboring foreign bodies, and managing these often poses a clinical challenge to even the most experienced emergency physicians. Much has been written on retained foreign bodies in traumatic wounds. The literature reviewed for this section focused specifically on hand wounds, since the sensation and anatomy of the hand may make the assessment of wounds here different from other body areas. In a review from a large medical malpractice insurance company, over a third of closed claims involved retained foreign bodies in finger/hand/arm wounds.[46]

Good wound exploration should identify most foreign bodies. This is more sensitive if the wound is probed, palpated, and the wound base is visualized, but studies suggest these measures alone are insufficient to completely exclude retained glass or other foreign bodies.[14,47,48] Retained glass is the most commonly reported retained hand foreign body, and mechanisms usually involve glass shattering in a hand or an upper extremity breaking through a glass window. Plain radiographs are very sensitive in picking up all types of glass foreign bodies > 2 mm in size.[49] Radiographs also identify rocks, gravel, metal, and other radio-opaque foreign bodies, but only rarely pick up plastic, wood, or other vegetable matter. Retained foreign bodies do increase infection rates, though

small foreign bodies deeply embedded may be best left in place.[46,50,51]

If the wound appears clear and the initial x-rays are normal, further studies may be indicated when a radiolucent foreign body is suspected. Multiple studies report the usefulness of ultrasound in detecting soft tissue foreign bodies,[52-54] although one randomized, controlled prospective study using a chicken-thigh model to simulate hand anatomy differed in opinion.[55] Perhaps the best existing RCT evaluating sonography in hand foreign bodies was performed on human cadaver hands with sensitivities of 95-100% for small (1-4 mm) and larger wooden foreign bodies of the palm and fingers.[56] The accuracy of ultrasound performed by emergency physicians to detect wound foreign bodies has yet to be prospectively studied. CT evaluation of wound foreign bodies is also very sensitive and, although generally more expensive than ultrasonography, is more readily available and less expensive than MR imaging.[57]

Bite Wounds

Bite wounds are responsible for nearly 1% of all ED visits in the United States, with dog bites accounting for 80-90% of cases.[58] In one prospective study, 50% of infected dog bites and 63% of infected cat bites occurred on the hand.[60] In a systematic Cochrane review in 2003, the authors concluded that there is no evidence that prophylactic antibiotics are effective for cat or dog bites, with *one notable exception*: bite wounds to the hand.[61] Prophylactic antibiotics significantly reduced the incidence of infection from 28% in the control group to 2% in the antibiotic group, when the bite wound affected the hand. The third most common bite wound in the United States is the human bite, and these frequently cause significant infections.[58,62] In a prospective, randomized study comparing placebo, oral antibiotics, and intravenous antibiotics in the management of uncomplicated human bites to the hand, nearly half of the admitted patients not receiving antibiotics developed an infection.[64] None of those receiving oral or intravenous antibiotics developed an infection. For a detailed discus-

Figure 9. Two-slab splint as described by Burkhalter.

The volar slab is placed first to hold the wrist in 30˚ extension (first image); then the dorsal slab is placed to the PIP joints with the MPs held at 90˚ extension (second image). Note free movement of the IP joints (third image).