American College of Emergency Physicians®

FORESIGHT

RISK MANAGEMENT FOR EMERGENCY PHYSICIANS ISSUE 55 • OCTOBER 2002

Avoidable Errors in Wound Management

OBJECTIVES

After reading this issue, you should be able to:

- Describe the management of high-risk wounds in the emergency department.
- Discuss the principles of wound evaluation that can help prevent allegations of misdiagnosis.
- Describe the general treatment of tendon lacerations, foreign bodies, and joint injuries and the prevention of wound infections.
- Explain the importance of arranging appropriate followup care for wounds at risk for complications and poor outcome.

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INTRODUCTION

Acute traumatic wounds are commonly seen and treated in emergency departments. The Centers for Disease Control and Prevention reports that, in the year 2000, an estimated 40.4 million visits to emergency departments were injury related. The most frequently recorded primary diagnosis was "open wounds," accounting for about 18% of all injury-related visits. The upper extremity (specifically, hand, wrist, and fingers) was most commonly listed as the site of injury, accounting for 12.6% of the total. Injuries to the foot accounted for 3.9% of all injury-related visits.[1]

Although wounds and wound complications represent 19% to 24% of all malpractice claim allegations, the amount of money spent on these cases is relatively low, about 3% to 4% of total indemnity and expenses paid.[2,3] Three specific allegations lead to most malpractice cases involving wounds: failure to diagnose the presence of a foreign body, failure to diagnose tendon or nerve injuries, and failure to identify infection-prone wounds and treat them accordingly. It is almost unheard of for a cosmetically unsatisfactory repair to result in litigation unless there is associated infection, retained foreign body, or nerve or tendon injury.

A focused history and physical examination, proper diagnostic tests, skilled procedural techniques, and timely consultation and/or referral will mitigate much of the risk involved in treating open wounds. The following scenarios illustrate issues involved in the treatment of acute traumatic wounds in the emergency department.

ON SIGHT – 1

Early on a Friday morning, Fred Stevens, a 42-year-old construction worker, is cutting a piece of steel when the band saw he is using jams and pulls his left hand into the blade. Mr. Stevens's coworkers apply a tourniquet to his forearm and take him to St. Agnes Memorial Hospital.

On arrival, the triage nurse notes that Mr. Stevens's hand is purple and loosens the tourniquet. She documents that he has good range of motion in the hand and that sensation is intact. She applies a pressure dressing and orders x-rays of the forearm and hand.

Kevin Jones, MD, performs a history and physical examination and reviews the x-rays. He notes that there is a laceration the width of the volar aspect of the patient's left wrist from the base of the thumb to the area of the ulnar styloid and that there are no fractures or foreign bodies. He notes somewhat limited dorsiflexion of the wrist and fingers but that the patient is too uncooperative to permit adequate motor and sensory examination. He does not document that Mr. Stevens is left-handed.

Dr. Jones then calls Jeff Trainer, MD, the orthopedist on call. After consulting with Dr. Trainer, Dr. Jones anesthetizes and sutures the wound. He places a volar splint, provides medication for pain, and discharges Mr. Stevens with instructions to follow up at the occupational medicine clinic the next day. A nurse gives Mr. Stevens directions to the clinic, along with a release from work pending evaluation by Dr. Trainer.

Mr. Stevens presents to the occupational medicine clinic as directed and is evaluated by John French, MD, a family practitioner. Mr. Stevens complains of numbness in the left ring and little fingers. Dr. French notes "slightly" decreased sensation over the same area. He sends Mr. Stevens home with instructions to elevate his arm to relieve the swelling and to continue his pain medication.

Mr. Stevens returns to the clinic 3 days later complaining of continued loss of sensation over his ring and little fingers and describes some weakness in his hand. He is seen by a different physician, who documents that the wound is clean and without signs of infection. The physician's note does not address the patient's complaint of loss of sensation, and no neurologic examination is documented. A compressive elastic dressing is placed, and Mr. Stevens is instructed to return in 1 week.

When Mr. Stevens returns to the clinic as instructed, he tells the nurse that his hand and fingers are still weak and numb. The physician on duty orders an EMG, which shows denervation of the ulnar nerve at the site of the laceration. Mr. Stevens is referred to a hand surgeon, who performs surgery 2 weeks later. The surgical procedure includes a nerve graft of the ulnar nerve, repair of the radial artery, and repair of the palmaris longus tendon and flexor digitorum superficialis tendons of the index and middle fingers.

Mr. Stevens requires postoperative rehabilitation and physical therapy for 6 months. He is able to return to his job after recuperating but has difficulty with intrinsic hand function and fine motor skills. He is unable to play sports or lift weights. He files a lawsuit against Dr. Jones and simultaneously files a Worker's Compensation claim. The other physicians involved are not named in the lawsuit.

INSIGHT – 1

The best way to diagnose tendon, nerve, or arterial injuries is a systematic approach to the history and physical examination. A dramatic presentation often elicits an emotional response, making a deliberate, orderly examination extremely important in preventing the inadvertent omission of important clues to the injury. After hearing a patient's description of the injury, the emergency physician should "replay" the event for the patient, confirming the factors involved. The physician must question the patient carefully regarding the possible presence of foreign bodies and the method of removal and must ask about any deficit in sensation or strength prior to the injury.

A rapid survey of the injury can be accomplished in an orderly way, as outlined in Table 1. In addition, Table 2 provides a quick reference for testing motor function of the peripheral nerves.

Table 1. Elements of wound evaluation.

Objective Findings	
Skin	Texture, turgor, wound, tenderness
Wound	Examine deep structure in a bloodless field
Vascular	Color, temperature, turgor, capillary refill, pulses
Bone and joint	Instability, deformity, tenderness
Muscle and tendon	Posture, strength, compartment pressure
Peripheral nerve function	Focused examination of motor and sensory function, including two-point discrimination or perception of pinprick
Subjective Findings	
Perception of injury	Pain or weakness
Skeletal	Pain at the site of injury, or indirect tenderness away from the site of the actual injury due to fracture or ligament injury
Muscle and tendon	Strength; unresisted, active motion may be limited, but when present, can confirm grossly intact tendons and innervation of the proximal muscles.

Table 2. Motor function of peripheral nerves.

Nerve	Motor Function
Radial	Wrist extension Digit extension
Ulnar	Finger abduction Finger adduction Thumb adduction
Median	Thumb flexion Thumb opposition Thumb abduction
Superficial peroneal	Foot eversion
Deep peroneal	Foot inversion Ankle dorsiflexion
Tibial	Ankle plantar flexion

HINDSIGHT – 1

Kevin Jones's documentation was not helpful in his defense. Although Mr. Stevens did present challenges in obtaining a thorough examination, Dr. Jones should have documented, as accurately as possible, something related to the condition of the skin, wound, vascularity, bone, joint, muscle, tendon, and peripheral nerve function. When Mr. Stevens presented to the occupational medicine clinic complaining of numbness in the left ring and little fingers, he should have been examined thoroughly and not simply sent home with instructions to elevate his arm and continue his pain medication. If a thorough motor and sensory examination had been performed, the nerve injury would have been diagnosed. A third opportunity to diagnose the nerve injury was missed when Mr. Stevens returned to the clinic 3 days later complaining of continued loss of sensation over his ring and little fingers with weakness in his hand.

Another problematic area in this case was the consultation and referral. Kevin Jones could have strengthened his case by documenting the consulting physician's recommendations on the chart, as simply as: "Per Dr. Trainer's instructions, will irrigate, close wound, and refer to his clinic for evaluation tomorrow."

Many hospitals now have affiliations with occupational health clinics that have contracts to provide services for certain companies. Depending on the contract, the emergency physician (or the patient) might be required to follow up at that occupational health clinic. Kevin Jones should have provided Mr. Stevens with written discharge instructions that included documentation of the consultation with Dr. Trainer and his agreement to see the patient in followup. This information might have prompted the other physicians to refer Mr. Stevens more quickly.

In light of the poor initial documentation and the delay in definitive diagnosis and treatment, the case against Kevin Jones was eventually settled in mediation, with $75,000 paid on his behalf.

- Obtain a focused history, with an emphasis on mechanism of injury.
- Perform careful neurovascular and tendon examinations on all patients with open wounds, and document carefully.
- Perform careful evaluation for retained foreign bodies on all patients with open wounds, which might include plain radiography or CT for metal or glass or an ultrasound examination for wood.
- Consult a hand surgeon for patients with suspected flexor tendon, nerve, or vascular injuries. Wounds that involve the joint capsule should be managed by a hand specialist. It is appropriate in some cases to temporarily close and splint a wound, but the emergency physician should ensure that the patient will be seen promptly by the consulting hand specialist.[4]

ON SIGHT – 2

Allen Glen, a 24-year-old outdoor enthusiast, is walking on a rocky beach in Hawaii when he slips and steps into a hole. He instantly feels a sharp, burning sensation in the sole of his bare foot. Alarmed by how deep the wound is and how much it is bleeding, he wraps his cotton shirt around his foot and goes to the local emergency department.

On arrival, the triage nurse notes that the wound is deep and bleeding briskly. She applies a compression wrap of gauze and documents "neurovascularly intact" in the triage note. She notifies Rich Jackson, MD, that she has a patient with a deep laceration to the sole of his foot.

When Dr. Jackson examines Mr. Glen, he notes that he has a 10-cm laceration on the plantar surface of his right foot that begins at the metatarsals and extends to the heel. He also documents "good pulses" and "normal" motor and sensory function.

Dr. Jackson instructs the emergency department tech to soak Mr. Glen's foot in saline and povidone-iodine solution and set up a suture tray. Following injection of a local anesthetic agent, Dr. Jackson closes the wound in two layers, first with 4.0 absorbable sutures, then with 3.0 nylon sutures. Dr. Jackson instructs the tech to bandage the wound, place a posterior splint, and give the patient crutches. Dr. Jackson tells Mr. Glen to come back in 7 to 10 days for suture removal.

Four days later, Mr. Glen returns complaining of severe pain and oozing from the wound site. Sylvia Fischer, MD, the emergency physician on duty, notes pus draining from between the sutures. After further discussion with the patient about the injury, Dr. Fischer decides to order an x-ray. It reveals a 4-cm linear foreign body and several smaller gravel-type foreign bodies.

Dr. Fischer consults the general surgeon on call and asks him to see Mr. Glen immediately. The general surgeon subsequently takes Mr. Glen to the OR, where he cleans and débrides the wound. He removes a long sea urchin spine and several small rocks, packs the wound open, and starts broad-spectrum intravenous antibiotic treatment.

Mr. Glen requires 14 days of hospitalization, including two more trips to the OR for débridement. He eventually requires skin grafting. After 6 months of rehabilitation and physical therapy, he walks with a limp. Mr. Glen ultimately decides to hire a lawyer and file a lawsuit against Dr. Jackson.

INSIGHT – 2

Although the discovery of a sea urchin spine as a retained foreign body is not a common experience for most mainland physicians, many of the principles of wound management (Figure 1) apply. In addition to a careful history and physical examination, the following areas should be considered.

Foreign Bodies

Foreign bodies associated with puncture wounds may or may not be visible on x-ray. Radiolucent foreign bodies may be detectable using ultrasonography. Any foreign body that contains pigment can cause discoloration of the skin. The presence of discoloration of any type should prompt the physician to explore the wound carefully for contamination. Black or purplish discoloration of the skin may result from dye leeched from the surface of certain types of sea urchins (*Diadema* spp). This discoloration does not necessarily mean that spines are retained in the wound, but if the discoloration persists after 48 to 72 hours, a spine fragment is likely to be present.[5]

All wounds should be examined for the presence of foreign bodies, and x-rays or ultrasound images should be obtained if a foreign body is suspected. All results should be documented. Sea urchin spines retained in a hand, a foot, or near a joint require surgical removal and débridement to minimize infection, inflammation, and damage to surrounding tissue structures. High-risk foreign material includes wood and other material capable of promoting an intense inflammatory reaction. High-risk areas include hands, feet, and over joints. Not all foreign bodies require removal: if retrieval may cause worsening of the injury and the foreign material is relatively nonreactive, the foreign body may be left (Figure 2).

Irrigation

Irrigation decreases bacterial count and removes smaller foreign bodies. A 30-cc syringe with an 18-gauge Angiocath or needle provides the proper pressure of 6 to 8 psi.[6] Sufficient pressures are not generated by bulb syringe or IV bag techniques. Wound soaking is not as effective as high-pressure irrigation and may actually increase bacterial counts and diminish the cellular immune response.

One study advocating irrigation with a pressurized canister of normal saline compared irrigation times and infection rates for wounds cleansed with syringe irrigation versus a new, single-use canister of pressurized (8 psi) sterile normal saline. The authors found that syringe irrigation times were nearly twice as long as the pressurized canister irrigation times.[7] Use of the pressurized canister facilitates ease of irrigation and markedly decreases the time involved in this traditionally labor-intensive activity. In addition, delivery of the saline is no longer operator dependent, ensuring generation of pressures appropriate for wound cleansing. The pressurized canisters may be useful in standardizing wound irrigation.

Antibiotics

The literature currently does not support the routine use of antibiotics for most wounds encountered in the emergency department, with the possible exception of human bites. Increased infection rates are seen in patients with gaping lacerations, foreign bodies, extremes of age, and debilitating illnesses such as diabetes mellitus. Because of this increased infection rate, wounds that some clinicians consider for antibiotic use include those for which closure is significantly delayed, those associated with a poor vascular supply, and those in patients who are very young or very old. In addition, wounds with potential foreign bodies and wounds contaminated by saliva or feces should be considered for antibiotic coverage.[8,9] Lacerations of the head and neck were associated with a decreased risk of infection.[10]

There is evidence from one trial that antibiotic prophylaxis reduces the risk of infection after human bites, but confirmatory research is required. There is no evidence that the use of prophylactic antibiotics is effective for cat or dog bites. There is evidence that antibiotic prophylaxis after bites to the hand reduces infection, but confirmatory research is required.[11] However, in the current legal climate, a poor outcome secondary to an infected injury will likely result in litigation or the threat of litigation. Emergency physicians must be able to defend their decisions to give or withhold antibiotics. One solution is to withhold antibiotics and have the patient return in 48 hours for a wound check. Although this involves an additional visit, it prevents unnecessary administration of antibiotics and the potential for increased bacterial resistance from antibiotic overuse.

When antibiotics are given, selection of the particular agent should be empiric. Dog, cat, and

Figure 1. Elements of proper wound management.

- An understanding of the mechanism and timing of injury
- An understanding of the potential for infection
- A well-documented evaluation for foreign bodies
- A well-documented evaluation of motor, sensory, and tendon function
- A well-documented evaluation of vascular status, including perfusion
- Proper wound preparation
- Sound wound closure techniques
- Judicious use of antibiotic therapy
- Appropriate tetanus prophylaxis when indicated
- Proper followup care
- Proper referral
- Setting proper expectations for the patient

Figure 2. Indications for foreign body removal.

Potential for inflammation or infection
- Vegetative or chemically reactive material
- Heavy bacterial contamination (eg, teeth, soil)
- Proximity to fractured bone
- Established infection
- Allergic reaction

Toxicity
- Spines with venom
- Heavy metals

Functional and cosmetic problems
- Impingement on nerves, vessels, or tendons
- Restriction of joint mobility
- Proximity to tendons
- Impairment of gait
- Persistent pain
- Cosmetic deformity (eg, tattooing)
- Psychological distress

Potential for later injury
- Intraarticular location
- Intravascular location
- Migration toward important structures

human bites can all be covered using amoxicillin-clavulanate as a first-line agent, although a first-generation cephalosporin plus penicillin (to cover *Pasteurella* and *Eikenella*) provides a less-expensive alternative. Plantar puncture wounds through athletic shoes and wounds contaminated by fresh water should include a fluoroquinolone to cover for *Pseudomonas*.

Antibiotic effectiveness requires achieving adequate blood levels as rapidly after wound contamination as possible. The surgical literature supports administration of antibiotics as rapidly as possible[12]; applying those principles to the small percentage of wounds that require prophylaxis in the emergency department, it is logical to assume that such prophylaxis should begin before manipulation of the tissues. This area is currently under investigation by academic emergency physicians and represents "leading edge" rather than standard medical practice at this time. The most important step in preventing wound infections is thorough cleansing and débridement.

Tetanus Prophylaxis

It is important to ask the patient the approximate date of his or her last tetanus immunization. Patients with high-risk wounds should be reimmunized if last immunized more than 5 years before. Those with low-risk wounds require immunization only if last immunized more than 10 years before. High-risk wounds are those older than 6 hours, or more than 1 cm deep, or stellate or avulsion, or visibly contaminated with dirt or saliva, or due to a missile or crush injury or frostbite. Patients who never received the initial series of three vaccinations (primarily the elderly and persons born overseas) should receive tetanus immune globulin and be given the first tetanus immunization, with arrangements for a second booster shot in 4 to 6 weeks and a third in 4 to 6 months. Administration of tetanus immunizations should follow recommendations endorsed by the CDC.

Wound Closure

The goals of wound closure are tissue repair, recovery of function, prevention of infection, and restoration of appearance. Primary wound closure is most successful when accomplished within 4 to 8 hours of injury; however, the site of the wound, amount of tissue damage, and degree of contamination are factors that influence outcome. Delayed primary closure is a technique best used for wounds at high risk of infection, such as heavily contaminated wounds, wounds from animal or human bites, and wounds with delayed presentation. Please note that there is no absolute time limit for wound closure; the location and degree of vascularity determine the time limits for closure. For example, scalp and face wounds heal well even when closed more than 24 hours after injury, but lacerations involving an extremity are more problematic if closure is delayed.

For delayed primary closure, the wound should be cleansed and left open, then covered with a moist dressing and closed in 4 to 5 days. Immobilization is warranted for wounds involving an extremity. Patients who are reliable and agree to delayed closure should be prepared for the fact that, even after 4 to 5 days, the probability of infection or the state of the tissue may require that the wound be allowed to heal by secondary intent (granulation without mechanical closure).

Again, although time limits for primary closure have been taught, there are no absolute limits prohibiting primary closure as long as the clinician carefully cleanses and inspects the wound before deciding whether to close it.

HINDSIGHT – 2

The legal battle between Mr. Glen and Rich Jackson was lengthy and costly in both monetary and psychological terms. Wound treatment is a controversial area, and "experts" abound. Dr. Jackson failed to document his examination for foreign body and failed to instruct the patient that there was a possibility of retained foreign body. He did not properly irrigate the wound, and he closed it "tightly." He failed to consider the contamination of the wound with organic material from the beach, and he failed to consider the impact of possible infection on a deep wound of the foot. Arguably, he should have referred the patient to a specialist due to the location and potential loss of function in a weight-bearing structure. The case eventually settled for $450,000.

- Always document that you examined the wound for retained foreign bodies (and do it).
- Discharge instructions should describe the possibility of retained foreign bodies and the signs of infection, as well as what the patient should look for and when to seek treatment.
- Irrigate wounds thoroughly, and consider delayed primary closure or closure by secondary intention for deeply contaminated wounds.
- If warranted based on mechanism of injury, perform a more thorough examination for foreign bodies, including the use of imaging studies.
- Consider antibiotics for infection-prone wounds, and warn the patient that antibiotics will not necessarily prevent wound infections.
- Above all, leave the door of communication open. Encourage the patient to ask questions and to return if he or she believes the wound is not healing as it should.

ON SIGHT – 3

Alex Stone is a 43-year-old computer analyst who loves to rock climb. He presents to the emergency department on a Wednesday afternoon complaining of pain in his right middle finger. He is triaged to fast track, where he is seen by Kellie Cloud, MD. The only triage note says, "Injured finger rock climbing 3 hours ago, neuro intact." Dr. Cloud evaluates Mr. Stone and notes an obvious deformity of the right middle finger at the proximal interphalangeal joint. An x-ray reveals a dorsal dislocation. Dr. Cloud preps the finger and places a digital block using 0.5% bupivacaine. After several attempts, the dislocation is reduced; postreduction films appear to confirm this. Dr. Cloud writes on the chart "discharge patient with a splint" but does not give specific instructions on how to splint the finger. An emergency department staff member splints the finger in full extension and discharges the patient with orthopedic followup in "1 to 2 weeks." A prescription for hydrocodone is given to Mr. Stone, as well as the telephone number of the orthopedist on call.

Mr. Stone visits the orthopedist 10 days later. The orthopedist notes that Mr. Stone still has significant pain and much difficulty with flexion of his right middle finger PIP joint. After consultation, Mr. Stone is referred to a hand surgeon. The hand surgeon suspects a volar plate injury and schedules Mr. Stone for surgery in order to attempt to improve function in the finger.

Although Mr. Stone is able to return to work 4 weeks later, his finger swells and hurts after he works a long shift. He has lost some function in his finger and contends that he cannot rock climb any more He seeks the advice of an attorney and files a lawsuit against Dr. Cloud and the hand surgeon.

INSIGHT – 3

The ligaments of the PIP joint are the most commonly injured in the hand. Dorsal dislocation is one of the most common hand injuries in the general population, and the most common among rock climbers.[13] Dorsal dislocation of the PIP joint is a result of axial loading and dorsal deviation, as results from a blow to an extended finger. Due to typical forces imposed on the fingers, volar dislocations are relatively uncommon. Lateral dislocation is the result of a tangential load applied to the extended digit that ruptures the collateral ligament and disrupts the volar plate. Rock climbers have been shown to have microscopic tears of the collateral ligaments of the PIP joints, presumably from repeated trauma. Preventive taping is recommended in avid climbers to avoid further ligament strain but does not fully protect from dislocation.

Pure dorsal dislocations at the PIP joint are usually stable after reduction and have about the same prognosis as a bad sprain of any joint. By comparison, volar dislocations or dislocations with a lateral component are often unstable after reduction and are more prone to complications such as progressive contractures, angulation, and osteoarthritis. Fracture dislocations of the PIP joint are usually dorsal, with a small volar plate avulsion fracture. If the volar fracture fragment is less than one third of the articular surface, these are usually stable after reduction. If the volar fracture fragment is greater than one third of the articular surface, it is intrinsically unstable and will have persistent subluxation if not addressed surgically.

A thorough physical examination with good documentation of active and passive range of motion is required after reduction; however, examination may be difficult or impossible due to swelling and discomfort. The use of a digital block for anesthesia will remove the element of pain from testing the active and passive range of motion after reduction. Fear that examination will cause a recurrence of the dislocation should be of little concern. If dislocation recurs, or if the joint remains deviated by more than 20 degrees compared to the unaffected side, ligament injury and instability should be suspected, and consultation with a hand surgeon (to arrange referral) is required. Any laceration with violation of the joint capsule suggests the need for hand surgery consultation.

Anesthesia for reduction of an interphalangeal dislocation can be achieved by either digital (base of the finger) or metacarpal (between the fingers) block. Inability to adequately reduce a dorsal dislocation may indicate entrapment of the volar plate, and consultation is required. Similarly, most volar and lateral dislocations are intrinsically unstable and require immobilization and timely referral.

If the joint is stable after reduction, 3 weeks of immobilization followed by physical therapy is indicated and should be conducted at the direction of a specialist. To reduce the risk of distraction of a possible volar plate fracture fragment, PIP injuries should be splinted in 30 to 35 degrees of flexion (to *prevent* full extension) until the consulting hand surgeon can examine the injury. If a fracture produces a volar plate fragment that is greater than 30 percent of the articular surface, surgical stabilization is likely to be needed. Prolonged immobilization in full extension results in contracture of the collateral ligaments and restricted finger flexion. To prevent this, fingers should be splinted in partial flexion; DIP and PIP joints should be splinted in 30 to 35 degrees of flexion, and MCP joints should be splinted in 60 to 70 degrees of flexion.[4] Pain and stiffness are likely

sequelae of a dislocation and may persist for 6 to 12 months following an injury. The patient should be forewarned of this.

Minimal charting requirements include a history of the injury, time of dislocation, any previous injury of the affected digit, full examination of active and passive range of motion, examination of neurovascular status, and a description of the deformity. Procedures should be adequately documented, followed by descriptions of the postreduction examination and x-rays. For all hand injuries, the prognosis and possibility of a fracture that is not immediately seen on x-ray should be discussed with the patient. Documentation of the need for further care and the likelihood of persistent pain and stiffness may prevent litigation.

HINDSIGHT – 3

The plaintiff argued that prolonged immobilization in full extension resulted in contracture of the collateral ligaments and restricted finger flexion. Kellie Cloud did not help her case by failing to make arrangements for physical therapy or by writing inadequate discharge instructions. The hand surgeon was dropped from the lawsuit, and the case against Dr. Cloud was ultimately settled out of court for an unspecified amount.

- After reducing a dislocation, perform a thorough physical examination with good documentation of active and passive range of motion.
- Inability to adequately reduce a dorsal dislocation may indicate entrapment of the volar plate, and consultation is required.
- To reduce the risk of distraction of a possible volar plate fracture fragment, splint PIP injuries in 30 to 35 degrees of flexion to prevent full extension.

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FORESIGHT

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