An Evidence-Based Approach To Traumatic Emergencies

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Neck Trauma: Don’t Put Your Neck On The Line
Orthopedic Sports Injuries: Off The Sidelines And Into The Emergency Department
Blunt Abdominal Trauma: Priorities, Procedures, And Pragmatic Thinking
Wrist Injuries: Emergency Imaging And Management

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An Evidence-Based Approach To Traumatic Emergencies

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AN EVIDENCE-BASED APPROACH TO EMERGENCY MEDICINE
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Goals & Objectives: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Discussion of Investigational Information: As part of the book, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration-approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product. Disclosure of Off-Label Usage: This book, An Evidence-Based Approach To Traumatic Emergencies, discusses no off-label use of any pharmaceutical product.

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In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: Dr. Matt S. Friedman, Dr. Benjamin Friedman, the original authors and peer reviewers for each chapter, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.

Method of Participation: Read the printed material and complete the Evaluation Form on page 129 or online at www.EBMedicine.net/CME. CME certificates will be sent to each participant scoring higher than 70%.

Hardware/Software Requirements: None required

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Class Of Evidence Definitions

Each action in the clinical pathways section of Emergency Medicine Practice receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling


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Welcome to Volume V in The Emergency Medicine Practice Clinical Excellence Series. Our primary goal is to update previous editions with recent publications to inform our readers of the latest evidence applicable to emergency medicine. Our secondary goals are to integrate evidence-based concepts into the daily practice of emergency medicine, to incite discussion, to further research, and to initiate modifications to the standard of care.

The articles selected for this book detail 4 distinct trauma topics, which are applicable to the trauma team in a level 1 trauma center, the solo emergency medicine practitioner in a 100-bed community hospital, and the ER doc moonlighting in an urgent care clinic. The literature on the management of trauma is vast and never stagnant. This book provides a focused discussion of neck trauma, orthopedic sports injuries, blunt abdominal trauma, and wrist injuries. These discussions allow emergency practitioners to remain knowledgeable and apprised of hot topics in our field in order to provide the best possible care for the patient.

Management of abdominal and neck trauma is variable in different shops across the country. Recent literature has addressed lingering questions and challenged old dogma. While less controversial, the management of orthopedic and wrist trauma is constantly manipulated to lessen the inconvenience to patients while increasing the efficiency of their treatment in the emergency room.

Emergency Medicine Practice strives to provide its readers with evidence-based perspectives on clinical care. This volume contains over 500 references, including 63 new references, with distinct, underlined paragraphs authored by the editors that offer the most recent updates, most of which relate to literature published in the last several years.

We hope that this volume of The Emergency Medicine Practice Clinical Excellence Series will fine tune your management of trauma and provoke inquiries into current practice. We also hope that you find our future volumes as insightful and helpful to your clinical practice.

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At 3:00 a.m. on a humid August morning, the telemetry nurse informs you that an ambulance is bringing in a 27-year-old male shot in the neck. Paramedics reported minimal blood at the scene. In the field, the paramedics applied a bandage and initiated 0.9 normal saline. Just as you step into the resuscitation room, a second call comes over the radio. Another ambulance is bringing in a 19-year-old unrestrained front seat passenger complaining of hoarseness and trouble breathing after striking her neck on the dash.

Whether at a busy level I trauma center or a small rural hospital, emergency clinicians must be familiar with the complex anatomy, pathophysiology, evaluation, and treatment of patients with penetrating and blunt neck trauma. Injuries range from obvious to subtle and can result in both immediate and delayed complications. Presentation can be dramatic in patients with penetrating airway and vascular injury or insidious as with blunt vascular dissection or missed esophageal disruption.

This chapter provides a comprehensive review of penetrating and blunt neck trauma with a focus on the evaluation and management of injuries to the airway, vascular, and digestive systems. (Please also see the October 2001 issue of Emergency Medicine Practice, “Cervical Spine Injury: A State-Of-The-Art Approach To Assessment And Management,” which is available online for subscribers at www.ebmedicine.net.)

Critical Appraisal Of The Literature

The majority of studies are retrospective reviews of various diagnostic modalities. In comparison to cervical spine injury, relatively few prospective studies address the ED management of blunt and penetrating neck trauma. Specific practice guidelines for these injuries are not adequately covered in the Advanced Trauma Life Support course, American College of Emergency Physicians clinical policies, or practice guideline Web sites. The institutional capabilities and current opinions of the radiologist and trauma surgeon on call dictate imaging studies and treatment.

Epidemiology

Incidents of penetrating neck trauma tend to cluster in specific urban areas and are often managed at level I trauma centers. At other hospitals, lack of familiarity and the complexity of the problem make this a “high-risk” situation for both the patient and the emergency clinician. Penetrating neck injuries account for 5% to 10% of all traumatic injuries and have an overall mortality of up to 10%.1 Most injuries to the neck are in zone II (between the cricoid and angle of the jaw).2

Blunt neck trauma is less frequent and dramatic, yet it is equally life threatening. Although vascular injuries predominate in penetrating trauma, airway injuries prevail in blunt trauma. Blunt neck injuries are often initially overlooked in the setting of multisystem trauma.3 The neck’s complex framework of supporting fascial planes, musculature, and cartilage result in minimal physical findings and delayed complications.4 A high index of suspicion is essential to avoid significant morbidity and mortality from delayed infection, airway obstruction, or cerebrovascular events.

The prevalence of blunt carotid injury varies widely among studies. In 1 series, there were only
49 patients with blunt carotid injury identified at 11 trauma centers for 6 years.\(^5\) Other reviews place the prevalence between 0.1% and 0.33%.\(^6,7\)

Fortunately, the incidence of neck trauma has not increased during the past 5 years. But considerable research has been published recently, with many long-term studies reaching their desired power, enabling further insight into the best management of critical neck trauma. One sonographic study published in 2008 noted that carotid artery injuries result from penetrating trauma 80% of the time, whereas vertebral artery injuries are much more common in blunt trauma.\(^8\) It is difficult to expound on previous data when the incidence is so low, even at trauma centers. Tracheobronchial injuries occur even less commonly than vascular trauma. In 12,789 trauma patients presenting to an ED, only 16 (0.13%) had tracheobronchial injuries.\(^9\)

**Anatomy**

Complexity and proximity define the challenging anatomy of the neck. The respiratory, vascular, nervous, gastrointestinal, skeletal, endocrine, and lymphatic systems all traverse the narrow confines of this space. The structures of the anterior neck are especially vulnerable.

To simplify the approach to injuries, current trauma literature divides the neck anatomically into zones. (See Figure 1.) Zone I, between the sternal notch and the cricoid cartilage, contains the proximal subclavian, vertebral, and carotid arteries, apices of the lung and trachea, esophagus, thoracic duct, and thyroid and parathyroid glands. Zone II, between the cricoid cartilage and angle of the mandible, contains the carotid and vertebral arteries, trachea, larynx, esophagus, spinal cord, and vagus and recurrent laryngeal nerves. Zone III, above the angle of the mandible, contains the pharynx, salivary glands, distal carotid and vertebral arteries, and several cranial nerves.

Zone II injuries are the most common and have the best prognosis. The anatomy allows relatively simple surgical exposure, application of direct pressure, and control of vessels.\(^10\) Exposure and control of injury is much more difficult with zone I and III injuries. Zone I injuries have the highest mortality secondary to involvement of intrathoracic structures; hemorthorax, pneumothorax, and great vessel injury are common.

Because of its exposure during physical examination, zone II injuries are the most clinically obvious and tend not to lead to occult injuries.\(^11\) However, most carotid injuries are associated with zone II injuries.\(^11\) This is because zone I is partially protected by the bony thorax and clavicle and the mandibular ramus provides protection to critical zone III structures such as the internal carotid, internal jugular, and cranial nerves.\(^12\) However, zone II is relatively vulnerable to an anterior insult, explaining the association with carotid injuries.

The neck is also divided into triangles. The anterior triangle is bordered laterally by the anterior border of the sternocleidomastoid, superiorly by the inferior mandible, and medially by the anterior midline of the neck. Injuries to the anterior triangle permit easy access for initial evaluation and surgical management. The posterior triangle is bordered posteriorly by the anterior surface of the trapezius, anteriorly by the posterior surface of the sternocleidomastoid, and inferiorly by the middle third of the clavicle. Injuries to the posterior triangle defy simple evaluation or control.

The neck is further divided into fascial planes. The platysma, a broad thin sheet of muscle extending from the facial muscles to the thorax, is a traditional surgical landmark for penetrating trauma. Wounds that penetrate the platysma require surgical consultation. The platysma is covered by superficial fascia anteriorly and the deep fascia posteriorly. The deep fascial layers of the neck include the investing, pretracheal, and prevertebral fascia. These 3 fascial layers help support the neck and may contain hemorrhage within a single compartment. The pretracheal fascia is continuous with the anterior pericardium, providing a route for infection to spread to the mediastinum in patients with aerodigestive tract injury. (See Figure 2.)

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Pathophysiology

For the purpose of this chapter, neck trauma is divided into penetrating, blunt, and strangulation injury. The pathophysiology of penetrating injury varies with mechanism. Gunshot wounds may be divided into low- and high-energy wounds. A high-velocity military assault rifle fired into the neck at 50 feet (15 meters) will produce more extensive tissue damage than a low-velocity handgun fired from the same distance. In addition to energy, multiple other factors determine the extent of injury, including mass, shape, fragmentation of the missile, and the tissue penetrated. Low-energy shotgun pellets follow erratic trajectories along the tissue pathway of least resistance and may result in pellet emboli to the heart or other organs. Stab wounds may leave a seemingly innocent wound, but the depth and path of penetration is difficult to predict. Descriptions regarding blade size, depth of penetration, and body position at impact may be misleading.

Gunshot wounds generally cause greater injury than stab wounds because of a bullet’s increased force, which penetrates deeper and causes cavitation, damaging structures outside the bullet tract. Higher velocity bullets generate a straight and predictable path as opposed to the erratic route from a handgun. These lower velocity (energy) missiles cause 50% fewer clinically significant injuries because of decreased bone and bullet fragmentation and lesser blast effects. In accordance with this, 75% of gunshot wounds to the neck necessitate surgical exploration, whereas only 50% of neck stab wounds require a surgical procedure.

Penetrating vascular injuries can be rapidly fatal from a variety of mechanisms. Although any large vessel injury can lead to hemorrhagic shock, carotid injuries can also produce a rapidly expanding hematoma that may distort or occlude the airway. Large lacerations of the jugular venous system can generate an air embolism, causing hypotension and respiratory distress.

Blunt neck trauma may initially go unrecognized because of more noticeable damage to the chest, abdomen, or head. Common mechanisms include a motor vehicle collision involving an unrestrained passenger decelerating against the dash (“the padded dash syndrome”), a shoulder harness creating shearing injury to the neck, and blunt neck trauma secondary to airbag deployment, clothesline, and bicycle handlebar injuries. Laryngeal trauma may result from a sharp blow to the anterior neck that compresses the thyroid and cricoid cartilages against the cervical spine.
Multiple mechanisms of vascular injury occur in blunt neck trauma. Direct blows to the anterior neck can compress the carotid, whereas blows to the head that cause rotation and hyperextension stretch the carotid artery across the cervical spine. Abrupt full flexion of the neck may crush the internal carotid artery between the angle of the mandible and upper cervical vertebrae, allowing delayed dissection. Carotid artery injury also occurs in the setting of blunt oral trauma and basilar skull fracture. Blunt carotid injury may occur in 0.7% of patients; patterns of injury include dissection, pseudoaneurysm formation, and thrombosis.

Blunt trauma causes 3% to 10% of cervical vascular injuries, and hyperextension of the neck is the most common cause. Diagnosing cervical vascular injuries quickly is crucial, as morbidity and mortality increase drastically if delays occur. Emergency clinicians frequently face situations in which severe injury has occurred with little obvious external trauma. Often, the only symptom of carotid injury is minor carotodynia: neck pain along the course of the artery. It is at these times when practitioners must be the most skeptical and order extensive radiologic studies in seemingly stable blunt trauma patients to avoid potential dire consequences.

Because the sympathetic fibers from the thoracic chain wind around the carotid artery, injury to the artery that disrupts these fibers will produce Horner’s syndrome (small pupil, droopy lid, and inability to sweat on the side of the face ipsilateral to the carotid injury). Because carotid disruption can produce ischemia to the ipsilateral cerebral cortex, patients may present with paralysis contralateral to the injured carotid. Blunt carotid injuries can also cause a rapidly expanding hematoma that can distort or occlude the airway.

Patients with vertebral artery trauma may present with a puzzling clinical picture. Some have vague complaints of visual changes, nausea, and vertigo. Notably, neurologic deficits do not relate to the particular vertebral artery involved. Because a clot in a vertebral artery will pass through the basilar artery and then into the posterior circulation, emboli from the right vertebral artery can travel to either the right or left posterior brain, resulting in a hodgepodge of cranial nerve deficits or alterations in mental status. Esophageal injury due to blunt trauma is extremely rare and should only be investigated when there are clinical findings suggestive of injury, such as significant pain on swallowing or the presence of unexplained subcutaneous air.

Different sources state that cerebral vascular trauma occurs in from 0.18% to 1.55% of all trauma patients. However, 2:1 internal carotid/vertebral artery involvement is generally agreed on. The variation may exist because the vertebral bodies offer significant protection to a posterior insult.

Traumatic arterial lesions, such as dissections, false aneurysms, or arteriovenous fistulas largely monopolize the literature, whereas venous lesions are often overlooked. One article attributes the effects of thrombosis of venous vasculature following penetrating trauma to the disruption to the venous epithelial lining. An intramural thrombus results generally within 48 hours, which can extend, leading to venous hypertension and increased intracranial pressure. A venous angiography might reveal delayed arterial transit time or filling of collateral veins; however, venous injury is most often suggested because of nonvisualization of the affected vasculature.

Having the critics praise you is like having the hangman say you’ve got a pretty neck.
—Eli Wallach

### Differential Diagnosis

Isolated injuries to the neck are the exception—multiple system injury and unexpected injury are the rule. The true path of a bullet may or may not follow a straight line between the entrance and exit wound (or from entrance wound to the final location of the bullet within the neck). Likewise, the depth and path of stab wounds are difficult to evaluate from external inspection. Strangulation survivors (especially those who have attempted to hang themselves) may appear stable on arrival only to decompensate dramatically hours after presentation.

During the secondary survey, the emergency clinician must methodically search for signs and symptoms of injury, system by system, as described in the following physical examination section. Even in the absence of hard findings, clinical suspicion combined with an organized diagnostic approach will provide the best and most cost-effective patient care.

Esophageal injuries are the least common but are the most frequently missed injuries in penetrating neck trauma. A low incidence and a lack of sensitive and specific clinical signs make the diagnosis of esophageal injury difficult. Furthermore, esophageal injuries may be masked by other injuries. One study of penetrating laryngotracheal injuries found esophageal injuries in 11 of 57 patients. In another study of esophageal injury, 35 of 48 patients had at least 1 other injury, with 9 patients having at least 3 other injuries. Delayed operative repair of esophageal injuries results in high morbidity and mortality due to early contamination of the paraesophageal space. Rapid diagnosis of occult esophageal injury must be a high priority in penetrating neck trauma.

Even stable, apparently uninjured patients with neck trauma need to be treated in a methodical, systematic manner. Esophageal injuries often have an insidious presentation, but a 24-hour delay in diag-
nosis increases mortality markedly. Esophageal and tracheal injuries are so rare that additional aerodigestive studies often seem like extraneous work. In an 8-year study including 12,780 consecutive trauma patients, only 12 (0.09%) had aerodigestive injuries. Other surveys found the injury rate closer to 5%, but the point should be taken that although rare, severe morbidity and mortality will be avoided by diagnosing these injuries early.

**Prehospital Care**

Information obtained by the paramedics may help determine the type of weapon used, range, position of the patient at the time of penetration, and trajectory. Within many urban settings, field triage criteria mandate transport of all penetrating neck trauma to the closest regional trauma center. On the other hand, patients with isolated blunt neck trauma may be taken to non–level I trauma centers, especially when there is no evidence of multisystem injury.

Airway management in the field by emergency medical technicians is fraught with unforeseen hazards. Hematomas and laryngotracheal injuries both necessitate and complicate initial airway management. Even common bag-valve-mask techniques may worsen injuries and distort anatomy by dissection of air into the surrounding tissues.

Indications for airway management in the field include long transport times with an unstable or potentially unstable patient, stridor or severe respiratory distress, apnea, and impending cardiopulmonary arrest. Orotracheal intubation allows direct assessment of the airway and placement of the airway with the fewest complications. Prehospital cricothyrotomy is indicated only with failed orotracheal intubation, entrapment at the scene with the need for a secure airway, or significant maxillofacial trauma in patients requiring airway management. If the cervical spine is at risk from either blunt or penetrating trauma, medics should immobilize the neck before transport.

Prehospital providers must perform a rapid assessment for tension pneumothorax and other immediate life threats. Intravenous lines should be inserted en route. In the presence of air sucking or bubbling neck wounds, apply an occlusive dressing to the wound. Some authorities suggest placing the patient in the Trendelenburg position to decrease the chance of fatal air embolism, although this recommendation has not been studied in a prospective fashion. Apply direct pressure to control active bleeding.

**ED Management**

**Initial Management**

As with any trauma patient, simultaneous evaluation and treatment begins with the ABCs of the primary trauma survey. Airway intervention may be necessary even before a patient is completely undressed and log rolled. Nurses should provide supplemental oxygen and establish vascular access shortly after patient arrival. Throughout the ED evaluation and management of trauma, any deterioration should trigger reassessment and stabilization of the ABCs.

**Airway Management**

If consciousness is impaired, open the airway with a jaw thrust in the setting of suspected cervical trauma or with a head tilt and chin lift in the absence of such injury. The timing of more definitive airway management is controversial. The fundamental principle, however, is that earlier intubation leads to easier intubation. Earlier intubation allows less time for anatomical distortion and patient deterioration. “Playing it safe” by intubating early decreases the need for later crash intubation away from the “friendly confines” of the ED.

In a large retrospective study, Eggen et al defined the following criteria for emergent intubation: severe respiratory distress, airway compromise from blood or secretions, extensive subcutaneous emphysema, tracheal shift, or alteration in mental status. They recommend elective prophylactic intubation for minimally symptomatic patients in case of suspected progressive airway compromise or if such a patient is likely to be out of the ED for a prolonged time for diagnostic studies. Walls et al suggest intubation for all gunshot wounds to the neck regardless of evidence of vascular or direct airway injury.

Radiographic clearance of the cervical spine is not necessary before airway manipulation when an experienced member of the team provides cervical spine immobilization. Rapid sequence intubation (RSI) may be performed with in-line cervical spine immobilization before formal radiographic clearance of the cervical spine. Unstable cervical injuries are rare with penetrating neck trauma in the presence of a neurologic examination without any positive findings.

Multiple retrospective studies demonstrate the potential difficulty of securing an airway in penetrating neck trauma. In a recent large retrospective review, Mandavia et al reported on 748 consecutive patients with penetrating neck trauma. Eighty-two (11%) required intubation; 6 out of the 39 patients who underwent RSI required multiple attempts, and 3 of 12 patients who initially underwent fiber-optic intubation required rescue RSI. In a retrospective analysis of 114 patients with penetrating neck trauma, Eggen et al reported that 26 of 69 intubation attempts were initially unsuccessful, with 6 requiring an alternative to endotracheal intubation.

The ideal method of airway management is also controversial. Management options for the patient with neck trauma in the ED include RSI, oral intubation with sedation or local airway anesthesia,
Orotracheal Intubation

Several retrospective reviews support orotracheal intubation as the initial modality of choice. Orotracheal intubation provides direct visualization of the vocal cords, the fewest complications, and the highest success rate. The familiarity of emergency clinicians with RSI makes this a preferred technique in the majority of patients with penetrating neck trauma. Mandavia et al reported that two-thirds of all critical airways were managed with RSI, with a 100% success rate, including 2 rescue cases of failed fiber-optic intubations. Likewise, in the anesthesia literature, Shearer and Giesecke had a 98% success rate using RSI in patients with penetrating neck trauma.

To prevent the “can’t intubate/can’t ventilate” nightmare, avoid paralyzing patients who cannot easily be bagged. A morbidly obese male with a thick beard covering a small mouth should raise this concern. In addition, significant distortion of the airway due to expanding hematomas or direct airway trauma may render the bag-valve-mask impossible.

Oral intubation with sedation alone (awake intubation) is indicated when bag-mask ventilation may be difficult. Sedation is best performed with ketamine (1-2 mg/kg slow IV push) or rapid-acting reversible agents (such as midazolam 0.05 mg/kg or fentanyl 1-2 mcg/kg). Preservation of respiratory drive is the biggest advantage of ketamine. If time permits, have the patient breathe nebulized 4% lidocaine to anesthetize the airway and facilitate cooperation. Direct local airway anesthesia is another option; however, it may be difficult to perform on a moving target unless combined with adequate patient sedation.

Special caution is indicated in the patient with significant blunt or penetrating laryngeal injury. With blunt trauma, closed laryngeal injury may make orotracheal intubation impossible. With massive blunt laryngeal trauma in the patient maintaining an airway, avoid paralysis and prepare for an immediate surgical airway and neck exploration in the operating room. Awake intubation with local anesthesia and endotracheal intubation over a fiber-optic bronchoscope are other alternatives to consider in the difficult (and fortunately rare) case of blunt neck trauma with significant laryngeal injury.

With penetrating trauma, open injuries to the larynx may facilitate direct intubation of distal segments. Grasp the distal segment with a towel clip to stabilize the trachea and directly intubate through the neck wound. (See Figure 3.)

Beware the clothesline injury; this particularly lethal mechanism occurs when the rider of a motorcycle, snowmobile, or bicycle runs into an unseen wire or tree limb. In such a patient, the trachea may be transected, making RSI a dangerous procedure. Pharmacologic paralysis may result in loss of supporting muscle tone and misalignment of the discontinuous tracheal segments, which makes it impossible to ventilate or intubate—leaving the only therapeutic alternative an ED median sternotomy to look for the missing proximal trachea.

Alternative Approaches To The Airway

Use alternative airway approaches when orotracheal intubation is unsuccessful or contraindicated. Blind nasotracheal intubation is not generally recommended in patients with neck trauma; it can be especially dangerous when there is a possibility of dislodging a clot. In addition, the distorted anatomy leads to a higher failure rate for blind nasotracheal intubation. Intubation over a fiber-optic bronchoscope is time consuming, and a bloody airway makes it a challenging procedure even in experienced hands. Retrograde intubation using a guide wire inserted in the cricothyroid membrane and brought out through the mouth is often slow and requires experience and skill.

Although blind nasotracheal intubation has previously been discouraged because of the pos-
sibility of distorted anatomy or dislodging a clot, a study published in 2004 demonstrated a 90% success rate with prehospital patients using this technique. The mean number of attempts was 1.16 (range 1-4), and the mortality rate was 5%, similar to that in orotracheally intubated patients. Furthermore, none of the patients experienced the complications that previous literature has suggested. Although the study enrolled only 40 patients, it does advocate this procedure as an alternative approach, especially by emergency medical services (EMS) when orotracheal intubation cannot be achieved.

**Cricothyrotomy:** Surgical airways are often the rescue method of choice. Cricothyrotomy is a quick and easy procedure in the absence of anatomic distortion. Some believe that a horizontal incision directly through the skin into the cricothyroid membrane is preferred when landmarks are easily palpable, whereas an initial vertical incision may allow better identification of the cricothyroid membrane when there is swelling or anatomic distortion. Cricothyrotomy is contraindicated (or relatively contraindicated) in the presence of an expanding hematoma over the cricothyroid membrane. In patients with laryngeal trauma, tracheostomy is preferred over cricothyrotomy if time permits. However, if the patient with laryngeal trauma is dying of asphyxiation, perform an emergent cricothyrotomy (or needle cricothyrotomy).

**Percutaneous Transtracheal Ventilation:** Percutaneous transtracheal jet ventilation (needle cricothyrotomy) is a valuable airway rescue technique for patients with distorted anatomy who cannot be intubated orally. It is an alternative airway of choice for children younger than 8 years in whom cricothyrotomy is contraindicated. A large-bore catheter placed through the cricothyroid membrane provides up to an hour of ventilation until a formal tracheotomy can be performed by a surgeon.

Insert a 10- or 12-gauge needle through the cricothyroid membrane (directed toward the feet) while aspirating with a syringe. Once air is aspirated, advance the catheter, withdraw the needle, and secure the catheter. Attach the catheter to high-pressured ventilation tubing connected to the standard wall oxygen outlet at 55 pounds per square inch. A finger control valve can be used to achieve an inspiratory/expiratory ratio of at least 1:3 to avoid barotrauma. Percutaneous transtracheal ventilation devices are available commercially or can be constructed from parts available to any respiratory therapist. The emergency clinician should assemble this kit before it is needed, as the arrival of a patient with a compromised airway is no time to start searching for parts.

**Tracheostomy:** Although more difficult to perform, tracheostomy may be required when other techniques have failed and cricothyrotomy is contraindicated. Formal tracheostomy is usually left to the surgical consultant but may be accomplished by emergency clinicians experienced in the procedure. Airway approach recommendations by clinical presentation are reviewed in the “Clinical Pathways.”

**Breathing**

Patients with zone I injuries are especially prone to pneumothorax and hemothorax. The combination of hypotension, respiratory distress, and unilateral decreased breath sounds should prompt immediate needle thoracostomy followed by tube thoracostomy.

Many emergency clinicians argue that needle thoracostesis is an unnecessary step and that once a pneumothorax is suspected, tube thoracostomy should be initiated. Once the skin is incised, subcutaneous tissue dissected, and the pleural cavity penetrated, the pneumothorax will be decompressed. This should take as much time as needle thoracostesis. Only after decompressing the pneumothorax should the chest tube be inserted and properly positioned.

A chest tube is necessary after needle thoracentesis, so placing the chest tube first eliminates an unnecessary procedure. Additionally, there is a risk of penetrating important vasculature in the second intercostal space with thoracentesis, especially when the positioning is too medial. Thus for safety, speed, and a lower complication rate, many ED intensivists urge practitioners to proceed directly with tube thoracostomy.

Ultrasoundography is now readily used to check for pneumothoraces. The mechanics of how to do so are beyond the scope of this chapter; however, the sensitivity and specificity are well known to be above 95%. Although the average practitioner probably does not have the same expertise as those ultrasonographers in various studies, ultrasonography will undoubtedly aid the emergency clinician’s assessment of a patient with a potential pneumothorax.

**Circulation**

**Control Bleeding**

Use direct pressure to control bleeding. *Clamping of vessels—blind or otherwise—should never be done in the ED.* Only the trauma surgeon should clamp vessels, and then only in the operating room with appropriate exposure, as inappropriate use of a clamp can lead to ischemic cerebrovascular accident or iatrogenic nerve injury.

If the hemorrhage cannot be staunchened with pressure because the wound is particularly large and deep, consider the placement of a Foley catheter. Insert the Foley as far as possible, and inflate the balloon with water until the bleeding stops or resistance is felt. This technique is especially valu-
able in penetrating wounds to zone I. Because of involvement of the subclavian vessels, such bleeding is notoriously difficult to manage in the ED. Uncontrolled intrathoracic hemorrhage from a zone I injury may require an emergent thoracotomy. Ligation of simple venous injuries is acceptable in the setting of hemodynamic instability.

Vascular Access
Establish vascular access. Some authorities suggest placing the IV in the extremity opposite the injury, under the assumption that fluid or blood administered on the side of the injury is more likely to leak out any venous wound in the neck. However, this assertion is not well studied.

At least 2 large-bore IVs of crystalloid solution given “wide open” is a traditional standard in the hypotensive patient. However, the amount of fluid that should be given remains controversial. Despite the “common wisdom” of providing large-volume crystalloid resuscitation for traumatic shock, no controlled clinical trials demonstrate a benefit to early aggressive resuscitation (especially before control of bleeding). Animal data suggest that aggressive fluid resuscitation may actually increase bleeding in uncontrolled hemorrhage. One prehospital study examined this issue in a series of nearly 600 hypotensive patients with penetrating torso injuries. In this trial, strictly limiting prehospital fluids improved outcomes, and patients in this group demonstrated both lower mortality and fewer complications. However, the role of hypotensive resuscitation requires further study.

Cardiac Arrest
It comes as no surprise that cardiac arrest in the setting of penetrating neck trauma is a poor prognostic sign. Heroic interventions may include ED thoracotomy to crossclamp the aorta and perform open cardiac massage, obtain control of bleeding vessels, and possibly aspirate the right ventricle to treat air embolism.

Standard Trauma Interventions
If an impaled object is in place (eg, a knife or a stick), leave it alone (see Figure 4). Impaled objects may tamponade lacerated vessels; ED removal may precipitate life-threatening hemorrhage. Such objects should be removed in the operating room.

Most of the standard trauma interventions, such as monitoring vital signs and electrocardiogram, and Foley catheterization, remain unchanged in the patient with neck trauma, with 1 exception. The placement of a nasogastric tube is controversial, as some theorize that the tube may dislodge a clot and worsen the hemorrhage. Consult the treating surgeon in regard to this decision.

To repeat what others have said, requires education; to challenge it, requires brains.
—Mary Pettibone Poole, “A Glass Eye at a Keyhole,” 1938

History
Asking the patient his or her name provides immediate useful information regarding mental status and airway. No answer or a harsh or muffled voice should prompt immediate intervention.

Determine the mechanism of injury, weapons involved, number of shots fired (if it is a gunshot wound), and other details from the scene. When evaluating neck trauma, it may be helpful to divide the questions into organ-specific clusters. “Airway questions” would include any shortness of breath, difficulty speaking, pain with inspiration, and hemoptysis. Inquire whether the patient has pain with swallowing (an important clue to esophageal disruption). “Neurologic questions” would address numbness or weakness with special attention to whether the deficit is on the right versus left side (associated with carotid injury or stroke) as opposed to arms versus legs (more often linked with spinal injury). Ask whether the patient had associated head trauma or loss of consciousness. “Vascular questions” focus on blood loss, swelling of the neck, or the sound of “whooshing” in the ears (pulsatile tinnitus), which is associated with carotid dissection.

In assessing the past medical history, determine whether the patient has had any prior neck or chest surgeries and assess whether the patient is on warfarin or other medications that can affect hemostasis.

Physical Examination
Attention to the ABCs, vital signs, and mental status provides important clues regarding clinical stability. Inspect the airway for signs of injury, bleeding, and the patient’s ability to protect his or her airway. Assess breathing by looking for symmetrical chest rise

Figure 4. Knife In Neck

In cases of impalement, leave the implement alone! This knife should be removed in the operating room.
and fall, auscultating the neck and chest for stridor or other abnormal sounds, and palpating the neck and chest for obvious injury, subcutaneous emphysema, and hematomas. Circulation can be evaluated by palpating the arterial pulses in the neck, face, and extremities and assessing mental status, blood pressure, and heart rate. Check disability via the AVPU scale (Alert, responds to Verbal stimuli, responds to Painful stimuli, or is Unresponsive) or the Glasgow Coma Scale. Exposure is essential in all trauma patients, given the likelihood of multiple injuries, often incomplete histories, and delayed development of injury.

The secondary survey begins with a head-to-toe physical examination of the patient. Location of wounds and number of missiles may help direct the necessary workup. The secondary survey in neck trauma must focus on airway, digestive tract, vascular, and nervous system injury.

**Neck Examination**

Signs of laryngeal injury include pain or tenderness, hoarseness or voice alteration, stridor, subcutaneous emphysema, dysphagia, hemothorax, and deformity of external landmarks. Pay particular attention to the character of the patient’s voice. Any intrinsic laryngeal injuries can lead to hoarseness. Extrinsic laryngeal injuries resulting in voice changes include recurrent laryngeal nerve injury and extralaryngeal hematoma. Minimal initial voice changes and physical examination findings may progress into life-threatening injuries. Increasing intralaryngeal hematoma and edema may not reach the maximum until several hours postinjury, necessitating repeated examinations and close attention to respiratory status.³

The literature continues to differ on whether airway compromise will commonly be clinically evident on initial presentation. Eighty of 106 consecutive neck trauma patients who had tracheal injuries all presented to the ED with signs of airway compromise, such as tachypnea, dyspnea, cyanosis, subcutaneous emphysema, and abnormal respiration.⁵⁶ Contrasting that study, other researchers argue that breathing difficulty may not manifest until hours after initial presentation, and necessary studies should be ordered, even without obvious signs of tracheal injury.⁵⁷ Additionally, practitioners should also be aware of coughing, drooling, crepitation, and asymmetry as potential signs of tracheal injury.

The clinical findings associated with penetrating vascular injury to the neck may be obvious (eg, brisk bleeding accompanied by shock) or subtle and detectable only through careful physical examination. Signs of vascular injury (see Table 2) include expanding hematomas, carotid bruits/thrills, hemothorax, and cerebrovascular injury from air embolism.

Listen over the carotids for bruits (put the diaphragm inside a glove to avoid getting blood on the stethoscope in case of penetrating trauma). A bruit may provide an important clue to carotid dissection or injury.⁷ Inspect the wounds by gently separating wound edges to determine if the wound has penetrated the platysma; if so, a surgical consult is needed. Avoid probing past the platysma to prevent clot disruption and false passages and to prevent otherwise aggravating the injury.

### Table 2. Clinical Findings By System

- **Airway injury**
  - Voice changes
  - Respiratory compromise / stridor
  - Airway compromise
  - Subcutaneous emphysema
  - Hemothorax
  - Bubbling wound

- **Penetrating vascular injury**
  - Shock with or without active bleeding
  - Expanding or pulsatile hematoma
  - Brisk bleeding from wound site
  - Airway compromise
  - Decreased pulse (radial, ulnar, carotid, temporal, facial arteries)
  - Carotid bruit / thrill
  - Hemothorax
  - Air embolism
  - Cerebrovascular accident
  - Neurologic findings incongruent with head CT
  - Asymptomatic interval between trauma and symptoms with negative head CT
  - Ipsilateral headache
  - Ipsilateral Horner’s syndrome
  - Facial or neck pain

- **Blunt vascular injury**
  - Carotid artery injury
    - Hematoma lateral neck
    - Bruit over carotid
    - Horner’s syndrome
    - Transient ischemic attack
    - Aphasia
    - Contralateral hemiparesis

  - Vertebral artery injury
    - Ataxia
    - Vertigo
    - Nystagmus
    - Hemiparesis
    - Dysarthria
    - Diplopia

- **Digestive tract injury**
  - Pain on swallowing
  - Neck pain or tenderness
  - Resistance of neck to passive motion
  - Subcutaneous emphysema
  - Dysphagia
  - Bleeding from mouth or nasogastric tube
  - Clinical signs often non-diagnostic
The clinical signs of esophageal injuries include neck pain and tenderness, resistance to passive motion of the neck, subcutaneous emphysema, dyspnea, dysphagia, and bleeding from mouth or nasogastric tube.

A palpable thrill and a bruit on auscultation can be appreciated when an arteriovenous fistula is present, indicating the high-volume vascular channel from the high-pressure artery to a lesser flow adjacent vein. A pulsatile mass with a palpable thrill and an audible to and fro murmur signifies that a pseudoaneurysm lies underneath. The pseudoaneurysm forms by trauma to all 3 layers of the artery, forming a hematoma that is contained by the surrounding tissues and contiguous with the artery. Clinical signs that present after neck trauma can be categorized into the likelihood of vascular injury. “Hard signs” such as bruits, thrills, pulsatile or expanding hematomas, pulsatile or severe hemorrhage, and pulse deficits are highly indicative of vascular injury. “Soft signs” such as hypotension and shock; stable, nonpulsatile hematomas; parathesias; central or peripheral nervous system ischemia; or proximity to a major vascular structure are less predictive of vascular injury. These signs can be used to guide practitioners about the severity of an injury and the need to expedite surgical exploration.

Chest Examination
Palpation of the anterior chest may reveal subcutaneous air associated with pneumothorax. Listen for asymmetry of breath sounds, another important clue to air in the pleural space. Cardiac auscultation can demonstrate a crunching sound with each beat of the heart, a finding known as “Hamman’s crunch.” This sound can occur with any condition that leads pneumomediastinum; esophageal perforation is a rare but important cause.

Vascular Examination
In addition to evaluation of the carotids (eg, assess pulses, bleeding, hematomas, and bruits) carefully examine the peripheral pulses—most importantly the radial or brachial pulses. A deficit in an upper extremity pulse may signal a subclavian injury.

Neurologic Examination
Motor deficits may be secondary to stroke related to carotid artery injury, spinal cord damage, or injury to the peripheral nerves (in particular, the brachial plexus). In zone II injuries, carefully examine the cranial nerves; damage to the facial nerve produces a traumatic Bell’s palsy, whereas hypoglossal nerve injury will deviate the tongue. Clinical findings in blunt vascular injury depend on whether the carotid or vertebral artery is involved. Classic features include neurologic abnormalities incongruent with head computerized tomography (CT) (including stroke-like symptoms), a lucid interval between trauma and symptoms, ipsilateral headache, and facial or neck pain.

A 2005 study attempted to determine the frequency of stable versus unstable cervical spine fractures and the need for a cervical collar and spinal precautions in patients sustaining gunshot wounds to the face and neck. The cervical collar poses significant hindrance—especially in neck trauma—to lifesaving airway or vascular procedures. Emergency practitioners often struggle to maintain in-line cervical stabilization while grappling with intubations or surgical airways. Of 65 patients who were awake and alert without a neurological deficit, none of them had an unstable fracture and only 5% had a stable one. Thus, c-collar and spinal precautions should not obstruct emergent airway or vascular procedures in awake and neurologically intact patients. However, a c-collar should be replaced once emergency procedures are finished, and more definitive imaging looking for occult fractures should be obtained.

Skin Examination
For patients with strangulation injury, the skin examination is revealing. Patients may present with petechiae in the face and neck and often demonstrate subconjunctival hemorrhage.

Diagnostic Maneuvers
There are several important diagnostic maneuvers that can greatly augment the physical examination. First, have the patient cough to determine if he or she has hemoptysis; then, have the patient swallow to check for dysphagia; and finally, listen to the patient speak to assess laryngeal function. A positive finding resulting from these challenges will prompt further evaluation of the airway, esophagus, and larynx, respectively.

Diagnostic Studies
An important early decision involves the decision “to test or to treat.” In a practical sense, this amounts to mandatory operation versus a strategy of selective operation combined with a targeted diagnostic evaluation. An even more controversial issue is selective testing, where testing is based on clinical findings and not the mere fact of neck injury.

Mandatory Versus Selective Operative Intervention
Mandatory neck exploration has mostly been supplanted by selective neck exploration of wounds that penetrate the platysma. During World War II, all wounds penetrating the platysma were surgically explored. There are several advantages of emergent operating room exploration. A negative neck exploration involves only a short, simple procedure, fewer additional diagnostic tests, and a shorter length of stay in the hospital compared with other management strategies. Patients with negative neck explo-
rations require only a short period of observation and can avoid the disastrous complications of an occult vascular injury. However, mandatory exploration results in a high negative exploration rate with the resultant morbidity of needless explorations (although the morbidity of an exploration with negative findings is usually low).

During the 1990s, selective neck exploration of stable patients with penetrating injuries became the standard of care. Many surgeons questioned the need to apply lessons from high-velocity military weapons to civilian injuries. Asensio et al reviewed and combined data from 26 studies of mandatory and selective exploration that included more than 4000 patients. The percentage of surgeries with negative findings decreased from 46% in the mandatory group to 30% using a selective approach, with no change in the mortality rate. Many of these studies showed that selective neck exploration with selective ancillary diagnostic testing safely excludes injury while decreasing the negative exploration rate.

Indications for immediate operative intervention without further diagnostic evaluation are presented in Table 3. If immediate surgical exploration is not indicated, then further evaluation is required to exclude occult injuries.

Transcervical gunshot wounds remain an area of controversy. In a retrospective review by Hirshberg et al, of 41 patients with a transcervical gunshot wound, 83% had neck explorations with positive findings. However, in a more recent prospective study using a selective approach, only 21% of patients with transcervical gunshot wounds had a therapeutic operation. The difference among these numbers may relate to a baseline difference in acuity. In the study by Hirshberg et al, nearly 40% of the patients had evidence of life-threatening injuries on ED presentation.

In patients with penetrating neck trauma, selective management is considered safe and practical and is now routinely used. In a 2001 study, unstable hemodynamics, airway obstruction, active bleeding from the wound, or evidence of aerodigestive tract injuries were indications for an immediate surgical procedure, and 40 of 57 patients underwent neck exploration for one of these reasons. But the 17 patients who appeared stable on initial presentation had uneventful conservative treatment with a complete radiological workup with negative results and no need for a surgical procedure.

**Laboratory Investigation**

Laboratory investigation of significant blunt and penetrating neck trauma includes some initial (and often serial) measurements of hemoglobin or hematocrit. Patients who are hemodynamically unstable, significantly anemic, or show evidence of ongoing blood loss should receive a type and crossmatch or type and screen, depending on the clinical circumstances. Injury patients with known or suspected liver disease, patients on warfarin, or those with persistent bleeding are candidates for coagulation studies.

Early measurement of systemic acidosis (base deficit, lactate, or pH) can provide important clues to occult shock. It may also be helpful to follow the trend of acidosis over time to determine the success of the resuscitation.

**Radiology**

Chest and neck radiographs are an important part of the initial workup of blunt and penetrating neck trauma. The initial x-rays should always be done in the resuscitation room of the ED and not in the radiology suite. Positive findings on soft tissue neck radiographs (see Table 4, page 16.) include subcutaneous emphysema, prevertebral emphysema, and not in the radiology suite. Positive findings on soft-tissue neck radiographs (see Figure 5).

**Table 3. Indications For Immediate Operative Repair By System**

<table>
<thead>
<tr>
<th>System</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular</td>
<td>Shock</td>
</tr>
<tr>
<td></td>
<td>Pulse deficit (absent radial pulse)*</td>
</tr>
<tr>
<td></td>
<td>Uncontrolled bleeding</td>
</tr>
<tr>
<td></td>
<td>Rapidly expanding hematoma</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Stridor*</td>
</tr>
<tr>
<td></td>
<td>Hemothysis*</td>
</tr>
<tr>
<td></td>
<td>Dysphonia*</td>
</tr>
<tr>
<td>Digestive</td>
<td>Hematemesis*</td>
</tr>
<tr>
<td></td>
<td>Dysphagia*</td>
</tr>
<tr>
<td>Neurologic</td>
<td>Neurologic deficits*</td>
</tr>
</tbody>
</table>

*In conjunction with other clinical findings

**Figure 5. X-ray Of Zone I Injury**

Zone I injuries are often associated with severe trauma to intrathoracic structures. Always obtain a chest x-ray in patients with these injuries.
bral emphysema, and the location of any missile or fragment. Chest x-ray may reveal pneumothorax, hemothorax, mediastinal air, widened mediastinal structures, and the location of missile fragments. In a retrospective study of 110 patients with bullet wounds to the neck, 48 patients had positive chest x-ray findings, including 6 with hemothoraces, 9 with pneumothoraces, and 4 with hemopneumothoraces.\(^{68}\)

Aerodigestive injury most commonly creates subcutaneous emphysema as the initial presenting sign. Fortunately, predictable air patterns on x-rays indicate the most likely injury. Laryngeal trauma leads to significant deep and superficial cervicofacial emphysema, whereas patients with tracheal injury often have vast mediastinal and deep cervical emphysema without pneumothorax.\(^{69}\)

**Targeted Diagnostic Strategies**

All of the following diagnostic algorithms depend on a central premise—that the patient is clinically stable. Most unstable patients, as well as patients who become unstable, need to go to the operating room without diagnostic delay. An exception would include those in whom interventional angiography may be lifesaving.

**Airway Injuries**

Airway evaluation is essential for patients with a change in voice, subcutaneous air, hemoptysis, or respiratory difficulties. Conversely, the absence of clinical findings reliably excludes laryngeal trauma in both blunt and penetrating laryngeal injuries.\(^{28,70}\)

The diagnostic evaluation of penetrating and blunt airway injury begins with visualization of the endolarynx via a fiber-optic scope or indirect or direct laryngoscopy.\(^{3,15,71-73}\) Laryngoscopy is indicated with positive clinical findings or a significant mechanism to evaluate the extent of intraluminal injury.\(^4\) Conventional radiographic evaluation serves as an important adjunctive role. Findings on soft tissue cervical radiographs include subcutaneous or prevertebral air or a fractured calcified larynx.

CT scanning plays a central role in the evaluation of suspected airway injury, especially in the case of suspected laryngeal involvement. It accurately identifies the location and extent of laryngeal fractures.\(^{74-77}\) Perform CT when the diagnosis of laryngeal fracture is suspected, even in the presence of an endolarynx examination without any positive findings or when the endolarynx cannot be visualized (intubated patients). CT findings determine the need for operative intervention and guide preoperative planning in displaced fractures.\(^{28,78}\) Laryngeal injuries are classified into 4 groups depending on the degree of injury. (See Table 5.)

Selective management is now the norm for patients post–neck trauma because of the wide array of tools we have to evaluate airway injuries. A combination of physical examination, plain radiographs, CT scans, and bronchoscopy should be used to assess patients. CT scanners, with their improved speed, enhanced resolution of images, and reconstructive abilities, have obviated the need for routine bronchoscopy to determine laryngeal or tracheal injury.

**Vascular Injuries**

**Angiography**

Angiography has been the traditional criterion standard in the diagnosis of vascular injuries. However, the best method of vascular imaging in penetrating injuries continues to evolve as newer and less invasive imaging techniques become more widely available. In zone III injuries, angiography may play both a therapeutic and a diagnostic role.

**Carotid Duplex Scanning**

Proponents of carotid duplex scanning point to the invasive nature and high cost of routine angiography. Multiple studies comparing angiography with

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**Table 4. Important Neck And Chest Radiograph Findings In Neck Trauma**

<table>
<thead>
<tr>
<th>Neck</th>
<th>Chest</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Subcutaneous emphysema</td>
<td>• Pneumothorax</td>
</tr>
<tr>
<td>• Prevertebral emphysema</td>
<td>• Hemothorax</td>
</tr>
<tr>
<td>• Missile fragments</td>
<td>• Mediastinal air</td>
</tr>
<tr>
<td>• Fractured calcified larynx</td>
<td>• Pleural effusion</td>
</tr>
<tr>
<td></td>
<td>• Widened mediastinum</td>
</tr>
<tr>
<td></td>
<td>• Missile fragments</td>
</tr>
</tbody>
</table>

**Table 5. Laryngeal Injury Classification By Schaefer**

<table>
<thead>
<tr>
<th>Group</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor endolaryngeal hematoma or lacerations, absence of detectable laryngeal fractures, and minimal airway compromise</td>
</tr>
<tr>
<td>2</td>
<td>Edema, hematoma or minor mucosal disruption without exposed cartilage, varying degrees of airway compromise</td>
</tr>
<tr>
<td>3</td>
<td>Massive edema, large mucosal lacerations, exposed cartilage, displaced fractures, vocalcord immobility, varying degrees of airway compromise</td>
</tr>
<tr>
<td>4</td>
<td>As in group 3, with disruption of the anterior larynx or unstable laryngeal cartilaginous skeleton</td>
</tr>
</tbody>
</table>

Immediate indications for airway management
- Stridor
- Respiratory distress
- Profound shock
- Rapidly expanding hematoma

NO

NO

Continue to re-evaluate airway status

Intubate
(Class I)
Options:
- RSI—if not difficult to bag and no anatomical disruption (airway of choice) (Class I)
- Awake intubation—if anticipated to be difficult to bag or suspected tracheal disruption (Class II)
- Fiberoptic intubation—if skilled operator and no significant blood in airway (Class II-III)
- Cricothyrotomy—can't RSI and no hematoma over cricothyroid membrane or laryngeal fracture (Class I-II)
- Needle cricothyrotomy—if child or other relative contraindication to cricothyrotomy (Class II)
- Tracheostomy—can't RSI and contraindications to cricothyrotomy (Class I-II)
- Direct tracheal intubation—open trachea (Class II)

YES

Immediate indications for airway management

YES

Urgent or prophylactic indications for airway management
- Progressive neck swelling
- Need to transfer symptomatic patient
- Voice changes
- Progressive symptoms
- Extensive subcutaneous emphysema, edema, or tracheal shift
- Alteration in mental status
- Prolonged time away from the ED for diagnostic study is anticipated and patient symptomatic

NO

For Class of Evidence Definitions, see page 1.
Clinical Pathway: Management Of Penetrating Neck Trauma

Platysma intact?  
YES → Local wound repair and discharge

NO →  
Patient unstable?  
YES →  
- Consult surgeon
- Resuscitate
- Manage airway
- Type and cross-match
- Direct pressure on bleeding sites
- Facilitate transfer to operating room or trauma center

NO →  
- Consult surgeon (Class I)
- Chest x-ray (Class I)
- Neck films (Class II-III)
- Hemoglobin/hematocrit (Class I-II)
- Lactate or base deficit (Class II-III)

Zone III  
(Above the angle of the jaw)  
YES →  
- Color-flow Doppler or CT angiography (Class II-III)
- Angiography (Class I-II)
- CT of head if suspected intracranial penetration or neurologic findings (Class I)
- Evaluate for esophageal injury if pain on swallowing or subcutaneous air (Class I)
  - Esophagoscopy (Class I-II)
  - Esophagography (Class I-II)
- Laryngoscopy or CT of neck (if clinical findings of airway injury) (Class II)
- Bronchoscopy (if clinical findings) (Class II-III)

NO →  
Zone I  
(Below the cricoid cartilage)  
YES →  
- Angiography (Class I-II)
- Color-flow Doppler or CT angiography (Class II-III)
- Evaluate for esophageal injury if pain on swallowing or subcutaneous air (Class I)
  - Esophagoscopy (Class I-II)
  - Esophagography (Class I-II)
- Laryngoscopy or CT of neck (if clinical findings of airway injury) (Class II)
- Bronchoscopy (if clinical findings) (Class II-III)

NO →  
Go to top of next page

For Class of Evidence Definitions, see page 1.

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Clinical Pathway: Management Of Penetrating Neck Trauma (continued from page 18)

Zone II
(Between the cricoid cartilage and angle of the jaw)

Indications for immediate operation?
- Shock
- Uncontrolled bleeding
- Rapidly expanding hematoma
- Pulse deficit (absent radial pulse)*
- Stridor*
- Hemoptysis*
- Dysphonia*
- Hematemesis*
- Dysphagia*
- Neurologic deficits*
  * In conjunction with other clinical findings

YES
- Facilitate transfer to operating room or to trauma center
- Resuscitate as possible

NO

- Abnormal voice
- Subcutaneous air
- Respiratory signs or symptoms
- Blood in airway

YES
- Laryngoscopy (fiberoptic or direct) (Class I-II)
- CT scan of larynx (Class I-II)
- Bronchoscopy (Class II-III)

NO

- Pain on swallowing
- Abnormal air on neck or chest x-ray
- Altered mental status

YES
- Contrast study of esophagus with radiocontrast oral agent. If negative, then contrast study with barium; if negative, then esophagoscopy.

NO

Go to top of next page

For Class of Evidence Definitions, see page 1.

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Clinical Pathway: Management Of Penetrating Neck Trauma (continued from page 19)

- Slowly expanding hematoma
- Carotid bruit or thrill
- Neurologic deficit unexplained by head CT or peripheral nerve injury
- Horner’s syndrome

**YES**
- Angiography (Class I)
- Color-flow Doppler (Class II-III)
- Helical CT angiogram (Class II-III)

**NO**

Stable, asymptomatic patient with Zone II injury*

Option 1: Selective diagnostic testing

Admit for observation and serial examinations (Class I-II)

Option 2: Mandatory diagnostic testing

Vascular evaluation
- Angiography (Class II) OR
- Helical CT angiography (Class II-III) OR
- Color-flow Doppler (Class II-III)

Esophageal evaluation
- Contrast studies and endoscopy (Class II)

Airway evaluation
- Laryngoscopy and CT (Class II)

* Management of stable asymptomatic zone II injuries is very institution- and surgeon-dependent

For Class of Evidence Definitions, see page 1.

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Clinical Pathway: Management Of Blunt Neck Trauma

Patient unstable?

- Consult surgeon
- Resuscitate
- Manage airway
- Direct pressure on bleeding sites
- Facilitate transfer to operating room or trauma center

Chest x-ray (Class II-III)

- Altered mental status or intoxication
- Distracting injury
- Tenderness over cervical spine
- Neurologic deficit

Cervical spine films

- Abnormal voice
- Stridor
- Subcutaneous air
- Respiratory signs or symptoms
- Blood in airway

Laryngoscopy (fiberoptic or direct) (Class I-II)
- CT scan of larynx (Class I-II)
- Bronchoscopy (Class II-III)

Go to top of next page

For Class of Evidence Definitions, see page 1.

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Clinical Pathway: Management Of Blunt Neck Trauma (continued from page 21)

- Carotid bruit or thrill
- Unexplained neurologic deficit
- Horner's syndrome
- Basilar skull fracture through carotid canal
- Fracture through the foramen transversarium
- Severe flexion or extension cervical spine fracture
- Massive facial fractures
- Significant neck hematoma

YES

- Angiography (Class I)
- Color-flow Doppler (Class II-III)
- Helical CT angiogram (Class II-III)

NO

- Pain on swallowing

YES

Contrast study of esophagus with Gastrografin. If negative, then contrast study with barium; if negative, then esophagoscopy.

Note: Blunt esophageal trauma is extremely rare

NO

- Admit for observation and serial examinations (Class I-II)
- Discharge with close follow-up (Class I-II)

For Class of Evidence Definitions, see page 1.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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carotid duplex scanning have found the sensitivity of carotid duplex scanning in excluding vascular injury ranges from 90% to 100%. These studies recommend carotid duplex scanning to exclude injury in asymptomatic zone II and III penetrating injuries. Because of occasional false-positive studies, carotid duplex scanning with positive results should be followed by angiography to confirm the injury.

A 2008 article in the *Journal of Ultrasound in Medicine* supports color Doppler duplex scanning (CDDS) as the current first-line radiographic study for evaluation of vascular injuries, with reported sensitivity of 95% to 97% and accuracy of 95% to 98%. It is widely available, noninvasive, and accurate. However, some limitations, such as large hematomas, subcutaneous air, and large skin wounds or burns, can disrupt CDDS performance. Operator dependence and length of the examination may also be limiting factors.

**Helical CT Angiography**

Helical CT angiography (HCTA) is an alternative to both carotid duplex scanning and angiography in the evaluation of penetrating vascular injury. Several prospective studies have examined the role of CT in penetrating neck trauma. In a recent small study of 14 patients, Mazolewski et al demonstrated that dynamic CT was 100% sensitive in excluding vascular injury. In another study, Munera et al found that HCTA was 90% sensitive and 100% specific compared with angiography. Using direct and indirect signs of injury on HCTA, LeBlang et al reported a sensitivity of 100% and a specificity of 97%. Other centers have not had such compelling results; the Memphis center found HCTA to be less than 50% sensitive in detecting blunt carotid injuries.

Direct signs of vascular injury include wall irregularity, contrast extravasation, lack of vascular enhancement, and caliber changes. Indirect signs included bone or bullet fragments less than 5 mm from a major vessel, path of injury through a major vessel, and a hematoma in the carotid sheath. Artifact and scatter associated with metallic fragments can complicate interpretation. However, with more and larger studies, HCTA may become an appropriate screening tool for vascular injury in neck trauma.

**Magnetic Resonance Imaging**

Case reports demonstrate that magnetic resonance imaging (MRI) can reveal a variety of vascular lesions. However, MRI has not been used specifically in patients with neck trauma and is limited by cost and logistical constraints.

Strides have been made recently to increase the use of MRIs after blunt neck trauma to evaluate vascular injuries. Studies have always shown the proficiency of MRI at diagnosing cervical cord injury, but MRIs have also proven advantageous for assessing vertebral artery injury after blunt cervical spine trauma. A study of 36 patients reveals that the sensitivity and specificity of MRI for assessing vertebral artery injury were 100% and 84.6%, respectively.

Although the criterion standard for diagnosing vertebral artery injury was cervical 4-vessel arteriography with a sensitivity of 97%, MRIs provide a noninvasive, less time-consuming, and accurate alternative. At an age when increasing numbers of magnetic resonance (MR) machines are becoming more accessible in theory and moving closer physically to the ED, another new modality exists in the armory to assess and aid in the best management for the patient.

**Special Considerations In Penetrating Trauma**

Indications for immediate exploration of vascular injuries include shock, pulse deficit, and a rapidly expanding hematoma. In stable patients with penetrating neck injuries, diagnostic evaluation varies by the neck zone injured. For zone I injuries, perform angiography in all patients to exclude injury to intrathoracic vessels. In stable patients with indications for operative repair, angiography determines the need for thoracotomy before neck exploration to repair thoracic outlet vessels. For stable patients without indications for operative therapy, a small recent retrospective study has challenged the need for routine angiography. Of 138 zone I injuries from 5 level I trauma centers during 10 years, none of the 36 patients with normal physical examination and chest x-ray results had an arterial injury. The authors concluded that patients with normal physical examination and chest x-ray results may not require routine angiography.

Zone II injuries in patients with indications for a surgical procedure do not require diagnostic investigations before a surgical procedure because the anatomy allows the easy exploration and repair of injuries. The diagnostic approach to patients without indications for a surgical procedure is controversial because of the debate of the reliability of physical examinations to exclude serious vascular injuries in penetrating zone II neck injuries. Some centers rely on the physical examination to determine that patients require vascular imaging; other centers perform these studies routinely. It becomes a matter of local practice because the literature is so conflicted.

Some studies show that physical examination is a reliable determinant of who needs vascular imaging (angiography or color-flow Doppler). The authors reviewed 8 studies with a total of 1216 patients. Of the 837 patients observed without hard signs of injury, 5 (0.6%) patients had injuries that required intervention. Three prospective studies involving 688 patients with zone II injuries report a missed injury rate of less than 1% using physical examination alone in select patients. Because transcervical and gunshot wounds are considered “high risk,” many centers perform routine angiography on such patients despite a physical examination with normal findings.
Other studies have found a higher number of missed injuries when physical examination alone is used to detect vascular trauma. In a retrospective review, Meyer et al studied 113 asymptomatic zone II–injured patients who underwent arteriography, laryngotraceoscopy, esophageal contrast studies, and esophagoscopy followed by neck exploration. In these 113 patients, clinical assessment alone had only a 68% accuracy in detecting injuries (although most missed injuries were nonoperative in nature). In a study from South Africa of 393 consecutive stab wounds to the neck, clinical signs were absent in 30% of neck explorations with positive findings (defined as an injury to the pharynx, esophagus, trachea, or vascular structure). These studies and others support the authors’ recommendation that both physical examination and ancillary diagnostic testing are required to rule out vascular injury.

For zone III penetrating injuries, physical examination is not reliable in excluding vascular injuries. Angiography is recommended because high internal carotid injuries may be difficult to visualize at operation and embolization may provide the most effective care.

### Blunt Trauma

The prevalence of vascular injury in the setting of closed head injury is 0.08 to 1.00%. A recent 2-year prospective study of the trauma registry at the University of Tennessee reported a prevalence of blunt cerebrovascular injury in 1% of all blunt trauma patients. Ninety-three percent of lesions occur at the bifurcation of carotids or higher. Multiple vessel injuries are found in 40% to 80%. In 1 study of 66 patients with blunt carotid injury, angiographic findings included 54 intimal dissections, 11 pseudoaneurysms, 17 thromboses, 4 carotid cavernous fistulas, and 1 transected internal carotid artery.

The diagnosis of vascular injury in blunt trauma is difficult. Coexisting injuries mask the clinical signs of carotid or vertebral injury, and 25% to 50% of patients have no external signs of neck trauma. Delayed neurologic deficits are the rule rather than the exception. More than 90% of patients are asymptomatic from hours to weeks after the injury; however, 10% of patients experience a transient ischemic attack or cerebrovascular injury within 1 hour, and 17% develop symptoms days to weeks postinjury.

Indications for diagnostic investigation of suspected blunt vascular injury include positive screening criteria (as described later in this section), neurologic findings incongruent with head CT, and monoparesis or hemiparesis with normal mental status. In patients with neurologic deficits unexplained by CT findings, spinal cord injury, or peripheral nerve injury, the prevalence of vascular injury is 21%. In a series of 66 patients with blunt carotid artery injury, the conditions of 34% of patients were diagnosed by incompatible neurologic and CT findings, 43% by new onset neurologic deficits, and 23% by physical examination (neck injury, Horner’s syndrome).

Patients with altered mental status who have either significant external cervical trauma or basilar skull fracture should also be studied. In patients with a high-risk mechanism of injury (cervical hyperextension or hyperflexion, direct cervical blow, near hanging) and injury pattern (carotid canal, midface, and cervical spine fracture), 27% suffered vascular injuries.

Using screening criteria, the detection rate for injury is much higher. Rozycki et al performed HCTA or conventional angiography on 131 patients with a cervicothoracic seat belt sign. They found a 3% prevalence of occult vascular injury, a number significantly higher than that found in other studies (0.24%-0.86%). The presence of these vascular injuries was strongly associated with a Glasgow Coma Scale score of less than 14, severe associated injuries (an Injury Severity Score > 16), and a clavicle and/or first rib fracture.

However, 1 patient with blunt carotid injury presented with a Glasgow Coma Scale score of 15, normal neurologic examination results, and an ecchymosis (but no hematoma) over her right clavicle. During an 18-month period, Kerwin et al used the following criteria to screen 1935 patients for possible blunt vascular injury: anisocoria, unexplained hemiparesis or other neurologic deficit, basilar skull fracture through or near the carotid canal, fracture through the foramen transversarium, cerebrovascular injury/transient ischemic attack, massive epistaxis, severe flexion or extension cervical spine fracture, massive facial fractures, and neck hematoma. Forty-eight patients had a positive finding and underwent angiography. Injuries were identified in 21 (44%) patients. The overall prevalence of blunt carotid/vertebral injury was 2.5% of patients admitted. No patient screened for a neck hematoma alone had a carotid injury.

Almost 25% of blunt neck trauma patients first develop signs and symptoms of vascular injury 24 hours after presenting. Unfortunately, the frequent initial manifestation is a severe ischemic stroke secondary to a thromboembolic event. If the vascular injury is treated early, permanent neurologic sequelae are less likely. Rozycki’s study pointed out that a cervicothoracic seat belt sign raises the risk of vascular injury threefold. Patients with any external signs of trauma following blunt neck trauma should be given highest priority until they are reliably excluded with appropriate imaging.

Diagnostic imaging for blunt trauma with suspected vascular injury is institution specific and depends on equipment availability and the skill of the radiology investigators. Angiography is recommended in the severely injured and symptomatic patient. Color-flow Doppler ultrasonography may be used to screen lower risk patients. Color-flow Dop-
pler provides rapid identification and quantification of arterial dissection but is operator-dependent and unable to assess the upper extracranial and intracranial internal carotid arteries.

HCTA has been used as a screening modality for patients at risk for blunt carotid injury.6 However, the diagnostic accuracy has not been well established in blunt trauma. The use of HCTA did significantly decrease the time to diagnosis from 156 hours to 5.9 hours and demonstrated an increased detection rate of cervical arterial injuries.100

MR angiography accurately detects carotid and vertebral artery injuries.106-108 Reported sensitivity and specificity are greater than 95% for carotid artery dissection. MR angiography is currently recommended as a follow-up test for stable patients because it is difficult to perform in severely injured or unstable patients.7,107,108 Perform MR angiography as a screening tool in stable patients to assess for occult carotid injury in patients who have sustained blunt trauma with severe closed head injury.

Digital subtraction angiography (DSA) was the accepted criterion standard for imaging neck vessels; but as mentioned previously, newer, noninvasive techniques such as MR angiography, duplex sonography, and CT angiography have emerged. The trend away from DSA arose because of the increased risk with an invasive procedure, the length of the procedure, and the additional resources needed. MR angiography is not first line because it is less available than CT angiography and possibly prohibitively long, even for hemodynamically stable patients. However, faster MR machines that are positioned closer to EDs are challenging these concepts, conjuring an image that one day they may be as readily available as a CT scanner.

Color Doppler sonography’s pitfall is its reliance on operator ability and difficulty in imaging patients with difficult anatomy or neck hematomas. As the trend continues toward newer modalities, DSA’s only role may be for therapeutic interventions or further diagnostic investigations, given initial equivocal or nondiagnostic results.109

Although vascular neck injuries are well known to occur following penetrating trauma, they are much less commonly associated with blunt cervical trauma. The differences do not stop there. Penetrating injuries to the vertebral artery are easily recognized owing to clinical signs of hemorrhage or the trajectory of the object that penetrated. However, the first obvious signs of blunt arterial injury are generally those associated with verteobasilar ischemia or infarction when it is far too late to act. Thus, a high degree of suspicion should dictate management based on the mechanism.

One retrospective study looking at lateral cervical dislocations revealed a high risk of vertebral artery occlusion and distal infarction, necessitating conservative management.110 The study, published in 1992, recommends digitized or MR angiography diagnostic evaluations, somewhat antiquating itself, as newer radiological techniques exist to determine management.

Cervical fractures encompass higher risks than dislocations. A cervical fracture has an odds ratio of 2.6 for carotid injury and 30.6 for vertebral artery injury, indicating the potential severity of injury involved in a fracture and the higher association between blunt trauma and vertebral artery injuries.111 Even transverse process fractures alone have an odds ratio of 19.5 for vertebral artery injuries. Thus, cervical deformities in blunt trauma patients should prompt CT angiography looking for vasculature injury. Identifying a thrombus and preventing it from embolizing could result from the astute practitioner’s recognition of the risks associated with cervical injury.

Digestive Tract Injuries
Penetrating Trauma
The indications for diagnostic testing for esophageal injury in penetrating neck injury include any positive clinical findings (especially pain on swallowing), a projectile in proximity to or trajectory crossing the midline, a projectile beyond the limits of surgical exploration, and the presence of subcutaneous air on cervical or chest radiographs.30,63,112 In 1 prospective study, Demetriades et al found pain on swallowing water or saliva to be a sensitive sign.63 Their data indicated that normal physical examination results (no dysphagia, no hemoptysis on coughing, and no subcutaneous air) had a 100% negative predictive value for esophageal injury in awake patients. However, in a review, Weigelt et al found that physical examination was only 80% sensitive for esophageal injury.113

The exclusion of penetrating esophageal injury must include some combination of physical examination, plain radiographs, contrast radiographs, endoscopy, and surgical exploration. A patient with suspected esophageal injury may undergo several sequential tests (assuming that each study has negative results), usually starting with a radiocontrast oral agent, followed by barium swallow, and finally endoscopy. The importance of early detection and treatment of these injuries, with operative repair and antibiotics for the prevention of serious complications and death, cannot be overemphasized.

Plain radiographs, esophageal contrast studies, and esophagoscopy are frequently used together to assess for esophageal injuries; however, none of the tests in isolation has the sensitivity to reliably exclude these injuries. Plain radiographs of the neck may reveal subcutaneous emphysema or an increased prevertebral shadow. Chest x-ray findings suggestive of esophageal injury include pleural effusions, pneumothorax, mediastinal air, and widening of the superior mediastinum. Normal radiograph

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results do not reliably exclude injury. In 1 study, 6 of 17 patients with penetrating esophageal trauma had cervical and chest radiographs read as normal.\textsuperscript{112}

Multiple studies show that esophageal contrast studies have a sensitivity of only 50\% to 90\%,\textsuperscript{30,112} Many centers begin with a radiocontrast oral agent (because it causes less pleural irritation than barium should the contrast material leak from a perforation) followed by the more sensitive barium study if the a radiocontrast oral agent swallow is negative. If the results from both swallowing studies are negative, perform esophagoscopy. Three small studies suggest flexible endoscopy alone may be adequate, each reporting a sensitivity of 100\% and specificities of 83\% to 93\%.\textsuperscript{113-116} In another trial, rigid esophagoscopy demonstrated a higher diagnostic yield than flexible esophagoscopy.\textsuperscript{117} However, flexible endoscopy is easier to perform, is less likely to cause injury, allows evaluation of the stomach and duodenum, and does not require general anesthesia when compared with rigid endoscopy.\textsuperscript{115,116} In a study by Horwitz et al (Illustrated in Table 6), the combination of physical examination, barium swallow, and endoscopy missed no injuries.\textsuperscript{116}

Two groups report surgical exploration of all patients with abnormal soft tissue air without employing contrast studies or esophagoscopy, claiming low sensitivity of these tests.\textsuperscript{88,89} They recommend esophageal contrast studies and endoscopy only in zone I penetrating injuries if the wound approaches the mediastinum but not in zone II and zone III injuries, owing to overlying bony shadows and contractions of the pharyngeal muscles, which often make the studies technically inadequate. Others disagree with this aggressive operative strategy, pointing out that only 36\% of patients with penetrating neck trauma and subcutaneous emphysema require an operation.\textsuperscript{94}

Early detection of penetrating esophageal injuries remains paramount but difficult. Ninety percent of patients survive an esophageal injury if detected within 24 hours; but the rate decreases drastically afterward, usually from mediastinitis or other infectious complications. Clinical signs and symptoms, which are 80\% sensitive, include dysphagia, odynophagia, drooling, and hematemesis.\textsuperscript{118} At times, crepitus or subcutaneous emphysema may be the only indication that an esophageal injury is present.

Large-scale studies still have not been performed to assess CT sensitivity in diagnosing digestive tract injuries although there is hope that CT will prove to have 100\% negative predictive value. But until then, according to a 2007 review, a barium swallow and an endoscopy must follow a CT with normal findings if there is a high suspicion of esophageal perforation.\textsuperscript{58}

**Blunt Injury**

Esophageal injury is exceedingly rare in patients with blunt neck trauma. In the world’s literature, there are only 10 reported cases of esophageal injury due to blunt trauma.\textsuperscript{27} Diagnostic investigation for these injuries is unnecessary unless clinical findings are present. The classic clinical findings include subcutaneous air and pain on swallowing; however, these presentations are not unique to blunt esophageal injury and are found more commonly with laryngotracheal injuries.

**Strangulation Injury**

Up to 10\% of all violent deaths each year are due to strangulation. In many cases, physical findings are absent in nonfatal strangulation.\textsuperscript{119} Strangulation injury may be defined as any mechanism that produces compression of the neck. Proposed mechanisms include hanging, postural strangulation, ligature strangulation, and manual strangulation.\textsuperscript{120} With hanging, the patient’s body is either totally or partially suspended by a ligature. Transverse intimal tears at the bifurcation of the common carotid artery are common in judicial hangings.

Postural strangulation occurs when the patient’s neck is stretched over an object and then compressed by the pressure of her or his own body. Ligature strangulation results when a ligature is pulled around the neck. Half of all survivors of ligature strangulation have hyoid and laryngeal injuries. Manual strangulation is often associated with fracture of the larynx, hyoid bone, and thyroid cartilage. Autoerotic self-strangulation occurs when the patient (almost always a male) ties a ligature around his neck, masturbates, and then tightens the ligature to induce hypoxia near the moment of orgasm (presumably to increase sexual pleasure).\textsuperscript{121} This technique is sometimes employed in conjunction with inhaled nitrates.

The supposed mechanism of death in strangulation patients is progressive cerebral ischemia and hypoxia caused by compression of blood vessels in the neck. Pressure on the neck obstructs venous circulation, causing stagnant hypoxia. The resulting loss of consciousness and decreased muscle tone in the neck

<table>
<thead>
<tr>
<th>Table 6. Accuracy Of Independent Diagnostic Tests in Esophageal Injuries</th>
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<td><strong>Sensitivity</strong></td>
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<td>Physical examination</td>
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<tr>
<td>Contrast study</td>
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<td>Endoscopy</td>
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*Combination of all modalities missed no injuries

allow occlusion of the arterial circulation. Total blockage of the airway occurs later, when the full weight of the body creates enough pressure to occlude the trachea. Cervical spine injury is rare in patients who sustain near-strangulation or nonjudicial hangings; in-hospital death or complications are usually due to noncardiogenic pulmonary edema.\textsuperscript{112,113}

As in the case of blunt neck trauma, strangulation patients are often “underevaluated.” The patient may be intoxicated or appear hysterical. Abused women may minimize events and symptoms to avoid police involvement that they fear could worsen the cycle of domestic violence. History provided by witnesses may be purposely inaccurate. Clinical findings such as hoarseness and conjunctival hemorrhage may be misinterpreted as benign illness.\textsuperscript{119} Because hyperventilation may result from

## Risk Management Pitfalls For Neck Trauma

1. **“He was still breathing on his own! Airway management wasn’t indicated.”**
   In the setting of neck trauma, early intubation leads to easier intubation. Waiting to see if that pulsatile mass will continue to expand is never recommended. Elective or prophylactic intubation should be considered even for the mildly symptomatic—especially if swelling is progressive.

2. **“But the cric is the rescue procedure of choice!”**
   Cricothyrotomy is relatively contraindicated when an expanding hematoma is present over the cricothyroid membrane or the patient has a suspected laryngeal fracture. In such circumstances, tracheostomy is indicated if RSI should fail. In certain situations, fiber optics may be the modality of choice. Awake oral intubation with local airway anesthesia is also useful.

3. **“I had to explore to the full depths of the wound!”**
   With adequate lighting and good retraction, the superficial tissues can be spread to see if the platysma has been violated. Further exploration in the ED is not warranted. Aggressive deep probing to explore the depths of the wound is best left to the surgeon in the operating room.

4. **“It was a tiny neck wound! How was I supposed to know the path of the ice pick?”**
   You can’t, and so you must suspect the worst. Any wound that penetrates the platysma (or cannot be proven not to penetrate the platysma) should be aggressively treated as a penetrating neck injury.

5. **“The patient had no evidence of vascular injury on examination and his head CT results were normal! I thought he was being dramatic.”**
   About 25% to 50% of patients with vascular injury after blunt neck trauma have no external evidence of injury. Neurologic deficits not explained by head CT imaging are the hallmark of vascular injury in blunt neck trauma. Image the great vessels of the neck in such patients.

6. **“There was no evidence of a fractured larynx on the x-ray!”**
   Clearly visualizing a fractured larynx may not be possible unless the patient’s cartilage is calcified. Physical examination findings include voice changes, respiratory compromise, tenderness, deformity, subcutaneous emphysema, and abrasions. Carefully palpate the neck for subcutaneous air. CT scan and a thorough endolaryngeal examination are the diagnostic modalities of choice.

7. **“I had to assess for laryngeal injury before intubating!”**
   Save the patient—then get the study. CT scan can be used to assess the larynx while providing information on the vascular and gastrointestinal tract in the intubated patient.

8. **“I ran his workup by the book. I managed the airway, ordered vascular studies, and evaluated the larynx and esophagus.”**
   Why didn’t you call the surgeon the instant you saw the knife went through the platysma? Early surgical consultation is one of the cornerstones in the management of penetrating neck trauma.

9. **“The results of his examination was negative, but I still did an x-ray and an upper GI with barium!”**
   The lack of sensitive and specific clinical signs makes the diagnosis of esophageal injury difficult. Physical examination, neck and chest radiographs, contrast studies, and endoscopy should be used to exclude esophageal injury.

10. **“There was a fountain of blood. I had to start clamping and tying.”**
    Direct pressure is the best method to control bleeding. Clamping and blindly “tying off all the big bleeder’s” is best avoided in the ED.
airway edema and aspiration pneumonia, anxiety must always be a diagnosis of exclusion in the ED.

Few formal algorithms exist for the evaluation of strangulation injury. A high index of suspicion is essential to avoid delayed morbidity and mortality. Clinical evaluation may include pulse oximetry, chest and neck radiographs, angiography, HCTA, MR, carotid Doppler ultrasonography, pharyngoscopy, and fiber-optic laryngobronchoscopy, as described for blunt neck injuries. Admission or observation is prudent in survivors of hangings to monitor the development of noncardiogenic pulmonary edema.

**Pediatric Neck Trauma**

Several anatomical differences between children and adults affect ED management. In children, the larynx is higher and better protected, rendering it less susceptible to injury. Several studies suggest that the prevalence of pediatric penetrating neck trauma is increasing, with mortality rates of up to 40%. Gunshot wounds and glass and other types of stab wounds are responsible for the majority of penetrating injuries.

The evaluation and management of pediatric penetrating neck trauma parallels that of adults, with many of the same controversies. Indications for immediate operative intervention are identical to adults. The debate over diagnostic testing in the asymptomatic patient takes on added importance. Some authors argue that the workup itself may be dangerous in children because of the need for general anesthesia for endoscopy and the higher risk of iatrogenic injury with angiography. They argue that in stable, asymptomatic pediatric patients, observation without invasive diagnostic testing is a reasonable course of action. After stabilization, transport pediatric patients with penetrating neck trauma to a level I trauma center, preferably one with pediatric surgeons on call.

Although less common, significant blunt pediatric injuries are reported to be more devastating, have

### Cost- And Time-Effective Strategies For Neck Trauma

1. **Quickly check to see if the wound penetrates the platysma. If it does, call a surgeon—right then. Wounds that violate the platysma require surgical consultation.**
   
   **Caveat:** Carefully lift the wound edges enough to determine platysmal violation; anything beyond that is unnecessary and risky. Avoid blind probing, which could dislodge a clot.

2. **Employ simple, quick, and low-cost diagnostic maneuvers.**
   
   Have stable patients speak, cough, and swallow to determine whether they have an abnormal voice, hemoptysis, or dysphagia. Auscultate their carotid arteries for bruits. Use the physical examination and clinical maneuvers to determine the need for further testing (selective testing).

   **Caveat:** Any patient who cannot cooperate with a clinical examination, such as those who are intoxicated or comatose, needs either a surgical procedure or an objective test. Local practice will often determine whether testing strategies are selective (based on the clinical picture) or mandatory (all patients undergo a battery of diagnostic tests).

3. **Employ selective versus mandatory exploration and testing.**
   
   Limited data exist on the analysis of cost-effective strategies for blunt and strangulation neck injury. An algorithm validated by Demetria-des et al for penetrating neck trauma reduced emergent operative procedures and significantly decreased costs without missing significant injury. Similar protocols have been published in multiple other studies.

   **Caveat:** Selective operation and selective testing require strict adherence to established protocols and may be very labor intensive. Whether this strategy can be extended to all institutions (especially those without in-hospital surgical support) remains unclear. Surgical consultation is essential in determining diagnostic evaluation.

4. **Consider alternatives to angiography.**
   
   HCTA may soon replace screening angiography in the evaluation of neck injury. The use of color-flow carotid Doppler is already well established. In a study by Fry et al, color-flow Doppler cost $1200 less than angiography and resulted in no false-negative or false-positive injuries. Demetriades et al showed that the combination of physical examination and color-flow Doppler resulted in no significant missed injuries in patients with penetrating wounds to the neck.

   **Caveat:** Although color-flow Doppler is well studied in penetrating trauma of the neck, it is less well studied in blunt injuries. HCTA has great potential, and early prospective studies are encouraging; however, larger studies are needed before it becomes the standard of care.
a longer hospital course, and more often require a surgical procedure than do penetrating neck injuries. Typical mechanisms in children include minibike clothesline injuries and bicycle handlebar injuries. Blunt neck injuries more commonly present with respiratory distress. If endotracheal intubation appears difficult or impossible, intubation over a fiber-optic bronchoscope or formal tracheostomy are the preferred methods of airway management. Cricothyrotomy is contraindicated in patients younger than 5 to 10 years because of the potential for developing subglottic stenosis, although needle cricothyrotomy may be lifesaving. Adverse outcomes are often related to delays in diagnosis.

Pediatric strangulation injuries are likewise ruinous. Injuries involving car windows, window covering cords, cribs, high chairs, furniture, and clothing are common mechanisms in children younger than 5 years. Accidental strangulation with rope and cords predominate in younger children, whereas teens may be at risk for autoerotic asphyxia or suicide, with an increasing male/female predomiance with age. The initial airway, pulmonary, and nervous system injuries are often obvious, but delayed rises in intracranial pressure with “late herniations” have also been described. The extent of initial injury and the effectiveness of ED resuscitation were the main factors of successful outcomes.

We rationalize, we dissimilate, we pretend: we pretend that modern medicine is a rational science, all facts, no nonsense, and just what it seems. But we have only to tap its glossy veneer for it to split wide open, and reveal to us its roots and foundations, its old dark heart of metaphysics, mysticism, magic, and myth.

—Oliver Sacks, in Awakenings, 1987

Treatment

The definitive treatment of serious neck injuries is generally beyond the scope of this chapter and rests in the hands of surgical consultants. However, a brief discussion of management principles may be helpful to the emergency clinician.

Airway Injuries

Treatment begins with early aggressive airway management. Perform oral endotracheal intubation for patients with suspected group 1 and 2 injuries as described in Table 5. Cricothyrotomy is relatively contraindicated with significant laryngeal disruption. The utility of endotracheal intubation over a fiber-optic bronchoscope depends on availability, secretions and bleeding, and emergency clinician experience. In severe injuries, perform tracheostomy under local anesthesia with the patient awake and breathing spontaneously (such a procedure is traditionally left to an experienced surgeon). With tracheal transection and other severe injuries, RSI may convert a partial airway obstruction to a complete airway obstruction if supporting muscle tone is lost with paralysis.

Nondisplaced fractures are generally treated nonoperatively, whereas displaced fractures require early surgical intervention. Administer antibiotics in the ED in case of suspected aerodigestive injuries. Initial broad-spectrum antibiotics with anaerobic coverage include clindamycin 900 mg IV or ampicillin/sulbactam 3 g IV.

Vascular Injuries

Penetrating Trauma

Not all carotid injuries require surgical intervention. Nonoperative management of carotid injuries is indicated for clinically occult injuries, low-velocity injuries (such as stab wounds), intimal defects of less than 5 mm, and pseudoaneurysms of less than 5 mm. Patients with these conditions must have intact distal circulation and adhere to regular follow-up to detect progression of the injury.

Blunt Trauma

The management of vascular injuries in blunt trauma depends on the size of the lesions and the overall clinical picture. Options include observation, anticoagulation, antiplatelet agents, arterial reconstruction, endovascular stenting, and ligation. Although some data suggest that heparin improves outcome, none of the treatments are very successful; there is still a high stroke and mortality rate with all of the therapeutic options. A proposed grading and management scale is presented in Table 7.

Treatment of blunt vascular injury should aim at preventing thromboembolic complications (via anticoagulation) and maintaining the patency of the stenotic vessel. Endovascular stenting or surgical intervention (bypass graft, thrombectomy, or resection of aneurysm or stenoses) should be reserved for those patients who are symptomatic but cannot be treated by anticoagulation, as it may be contraindicated in a trauma patient. Treatment of venous injury should aim at avoiding progression of thrombus by avoiding dehydration and jugular venous lines, although intravenous anticoagulation should be contemplated and likely initiated.

Digestive Tract Injuries

Penetrating Trauma

Surgical repair and drainage of deep neck spaces are indicated for cervical esophageal and lower hypopharyngeal injuries, and early repair can decrease complications. Nonsurgical management is recommended for injuries to the upper portion of the hypopharynx.
Blunt Trauma
Management of blunt esophageal injury is based on the size of the perforation. Antibiotics with anaerobic activity are indicated for all patients with suspected aerodigestive injury. Surgical therapy is recommended for esophageal or large (> 2 cm) pharyngeal perforations and medical therapy for small (< 2 cm) pharyngeal perforations.\textsuperscript{137}

Strangulation Injuries
Treatment of patients with strangulation injuries begins with aggressive respiratory management for symptomatic patients. These patients are at high risk for progressive edema of the uvula, epiglottis, larynx, and vocal cords; pulmonary edema; pneumonia; and adult respiratory distress syndrome. Strangulation survivors are also at risk for posttraumatic stress disorder and other behavioral and psychiatric problems. Measures to decrease intracranial pressure are indicated for patients with significant neurologic deterioration with impending herniation. Seizure prophylaxis and control may be helpful. Blunt vascular, laryngeal, and esophageal injuries are managed as described.

Disposition
Admission is indicated for all patients with penetrating neck trauma that violates the platysma and for patients with significant blunt trauma. Close observation of initially benign appearing patients is required to detect delayed presentation of airway, vascular, digestive tract, and nervous system injury. Patients with significant mechanism, physical examination findings, or positive findings during imaging must be followed in an intensive care unit with ready access to the operating room. Patients initially stabilized in hospitals without continuous monitoring and immediate surgical support should be transferred to a level I trauma center. Focus on the airway of patients who require transfer, as they may lose it during transport. If in doubt, intubate.

If the platysma is intact, patients may be safely discharged in the absence of significant associated injury. Superficial neck injuries can be managed according to standard principles: Repair clean wounds less than 12 hours old, but high-risk wounds (old and/or very dirty wounds) should be left open to heal by secondary intention. Administer tetanus toxoid as indicated.

Patients reporting strangulation should be admitted for observation, further evaluation, and coordination of police and social services to secure a safe environment. Patients with historical features or clinical findings of prolonged strangulation (eg, attempted hangings) should either be admitted or observed for 6 to 8 hours because minimally symptomatic patients may develop delayed noncardiogenic pulmonary edema and other sequelae.\textsuperscript{118}

Table 7. Blunt Carotid Arterial Injury Grading Scale With Suggested Treatment

<table>
<thead>
<tr>
<th>Injury grade</th>
<th>Description</th>
<th>Treatment</th>
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<tr>
<td>I</td>
<td>Luminal irregularity or dissection with &lt; 25% luminal narrowing (non clinically significant narrowing)</td>
<td>Anti-platelet therapy vs. anticoagulation</td>
</tr>
<tr>
<td>II</td>
<td>Dissection or intramural hematoma with &gt; 25% luminal narrowing, intraluminal thrombus, or raised intimal flap (potentially clinically significant)</td>
<td>Surgical repair if accessible, Anticoagulation if surgically inaccessible</td>
</tr>
<tr>
<td>III</td>
<td>Pseudoaneurysm</td>
<td>Surgical repair if accessible, Stenting if surgically inaccessible</td>
</tr>
<tr>
<td>IV</td>
<td>Occlusion</td>
<td>Surgical repair if accessible, Anticoagulation if surgically inaccessible</td>
</tr>
<tr>
<td>V</td>
<td>Transection with free extravasation (usually lethal injuries)</td>
<td>Surgical repair if accessible, Balloon occlusion or embolization</td>
</tr>
</tbody>
</table>

approach to initial evaluation and management.

The evaluation of injuries to zones I and III is fairly straightforward and generally requires vascular imaging studies. Management of zone II injuries varies widely depending on the institution: Some centers perform mandatory exploration, some mandatory testing, and others rely on selective testing driven by the history, physical, and plain radiographs.

Angiography and carotid duplex scanning may be used together or independently to evaluate for vascular injury. HCTA may replace angiography as larger prospective studies determine its accuracy. CT scan is especially useful to evaluate laryngeal injury. Contrast studies and endoscopy may be used jointly to prevent the deadly consequences of esophageal perforation. Constant adherence to the ABCs and maintaining a high index of suspicion for airway, vascular, and gastrointestinal injury will help the emergency clinician provide effective care for adult and pediatric patients of neck trauma.

**References**

Evidence-based medicine requires a critical appraisal of the literature based on study methodology and number of participants. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, is included in bold type following the reference, where available. In addition, the most informative references cited in the chapter, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

502. (Retrospective; 57 patients)
34. Shearer VE, Giesecke AH. Airway management for patients with cervical spine injuries. *Anaesthesia*. 1994;49(10):900-903. (Retrospective; 393 patients)
46. Patel RG. Percutaneous transtracheal jet ventilation: a safe, quick, and temporary way to provide oxygenation and ventilation when conventional methods are unsuccessful. *Chest*. 1999;116(6):1689-1694. (Retrospective; 29 patients)


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**CME Questions**

1. **Most injuries to the neck:**
   a. Are in Zone I
   b. Are in Zone II
   c. Are in Zone III
   d. Are blunt carotid injuries

2. **Wounds that penetrate the platysma:**
   a. Always require surgical consultation
   b. Only require surgical consultation in cases of high-velocity injuries
   c. Only require surgical consultation if the emergency physician has trouble probing past the platysma
   d. Only require surgical consultation if the emergency physician is unable to clamp off the bleeding vessels

3. **Homer’s syndrome is defined as small pupil, droopy lid, and lack of ability to sweat on the side of the face ipsilateral to the carotid injury.**
   a. True
   b. False
4. Esophageal injuries:
a. Are the least common but are the most frequently missed injuries in penetrating neck trauma
b. Are difficult to diagnose because of their low incidence and lack of sensitive and specific clinical signs
c. May often be masked by other injuries
d. Must be diagnosed early, because delayed operative repair results in high morbidity and mortality due to early contamination of the paraesophageal space
e. All of the above

5. In which of the following circumstances is early intubation of the patient with neck trauma suggested?
a. Patients with acute respiratory distress or airway compromise from blood or secretions
b. Patients with gunshot wounds
c. Symptomatic patients who are likely to be out of the ED for a prolonged time for diagnostic studies
d. None of the above
e. All of the above

6. Neck pain and tenderness, resistance to passive motion of the neck, subcutaneous emphysema, dysphagia, and bleeding from mouth or nasogastric tube most likely suggest:
a. Pneumothorax
b. Blunt vascular injury
c. Air embolism
d. Esophageal injuries

7. To control bleeding in patients with neck trauma, emergency physicians should use direct pressure. Clamping of vessels should only be performed by a trauma surgeon.
a. True
b. False

8. Which of the following is not a possible sign of airway injury in patients with neck trauma?
a. Voice changes
b. Subcutaneous emphysema
c. Diplopia
d. Hemoptysis
e. Bubbling wound

9. The location and extent of laryngeal fractures is most accurately identified by:
a. Clinical examination.
b. Laryngoscopy.
c. CT scanning.
d. Neck radiographs.

10. In stable patients with penetrating neck injuries in Zone I, the best study to exclude injury to intrathoracic vessels is:
a. Angiography
b. MRI
c. CT scanning
d. Carotid duplex scanning

11. Which of the following most reliably excludes carotid or vertebral artery injury in blunt trauma?
a. No external signs of neck trauma
b. Absence of neurologic deficits
c. Absence of neck hematoma
d. Angiography

12. Which of the following is least likely to be associated with esophageal injury?
a. Pain on swallowing
b. Diplopia
c. Subcutaneous emphysema
d. Hemoptysis on coughing

13. Patients with penetrating neck trauma in whom the platysma is intact:
a. Should be admitted to the intensive care unit
b. Should be admitted for observation
c. Should be transferred to a Level I trauma center
d. May be safely discharged in the absence of significant associated injury

14. Which of the following is/are indication(s) for immediate exploration of vascular injuries?
a. Shock
b. Pulse deficit
c. A rapidly expanding hematoma
d. All of the above

15. Objects that are causing penetrating neck wounds should be removed by the emergency physician in the ED once the airway has been established.
a. True
b. False

16. Which of the following can cost-effectively help determine the need for further testing in a patient with neck trauma?
a. Having the patient cough to determine if he or she has hemoptysis
b. Having the patient swallow to check for dysphagia
c. Listening to the patient speak to assess laryngeal function
d. Auscultating the patient’s carotid arteries for bruises
e. All of the above
Friday night, 8:50 p.m.: Paramedics radio ahead—they are bringing in a local high school football player who was tackled during a game. He can’t feel or move anything below his waist. The news media are already at the hospital asking questions. The paramedics want to know whether they should start steroids. The on-call neurosurgeon is not answering his pages.

Sports injuries present unique challenges to the emergency clinician. From the little leaguer to the cardiac rehabilitation patient, millions of Americans participate in sports or fitness activities. Although an athletic injury rarely requires a life- or limb-saving intervention in the emergency department (ED), the personal impact on the player can be monumental. Emergency clinicians must be expert in the diagnosis and initial treatment of sports-related injuries.

Each year in the United States, an estimated 150 million adults participate in some type of non–work-related physical activity, and approximately 30 million children and adolescents participate in organized sports.¹ From July 2000 through June 2001, an estimated 4.3 million sports- and recreation-related injuries were treated in U.S. EDs, comprising 16% of all unintentional injury-related ED visits.² The percentage was highest for those 10 to 14 years old and lowest for those older than 45. Among all ages, rates were higher for males than for females.³ Males are most often injured during playground activities, cycling, football, and basketball. In girls, most injuries are caused by playground activities, basketball, cycling, and general exercise.¹

The most frequent diagnoses include strains/sprains (29.1%), fractures (20.5%), contusions/abrasions (20.1%), and lacerations (13.8%). The body parts most frequently involved are the ankles (12.1%), fingers (9.5%), face (9.2%), head (8.2%), and knees (8.1%). Overall, 2.3% of people with sports- and recreation-related injuries were hospitalized (see Table 1, page 38).¹

This chapter describes management strategies for common orthopedic sports injuries. Prior issues of Emergency Medicine Practice, such as the January 2000 issue on mild head trauma, the February 2000 issue on back pain, the October 2001 issue on cervical spine injuries, the November 2001 issue on wrist injuries, and the May 2002 issue on ankle injuries, also provide pertinent information.

When I played pro football, I never set out to hurt anybody deliberately, unless it was, you know, important, like a league game or something.
—Dick Butkus

Critical Appraisal Of The Literature

Sports medicine, which has long been more of an art, is slowly becoming more of a science. However, few large, randomized, controlled trials provide evidence for many of the treatments used for sports injuries. A recent study attempted to examine the evidence base of sports medicine research. In evaluating 4 major journals that present core research in sport and exercise medicine, it was noted that randomized, controlled trials comprised 10% or less of all original research articles. Observational/descriptive studies were the most commonly published study design. When good-quality research methods (randomized, controlled trials as well as case-control and cohort studies) were categorized together, the difference between sports journals and other medical
An Evidence-Based Approach To Traumatic Emergencies

Well-designed clinical decision rules such as the Ottawa knee and ankle rules are excellent examples of evidence-based medicine. Such rules begin with a derivation set (in these cases, indications for radiography) later confirmed in a prospective validation study.

**Prehospital Care**

Prehospital care personnel should first ensure adequate airway, breathing, and circulation. Medics should splint suspected fractures before moving the patient and straighten severely angulated fractures. Emergency practitioners should confirm neurovascular status in injured extremities before and after splinting. Helmets should be stabilized rather than removed in the field unless the helmet prevents control of a bleeding site or airway management.

**ED Evaluation: Shoulder Injuries**

The shoulder is composed of 3 joints—the glenohumeral (GH), the acromioclavicular (AC), and the sternoclavicular—and 1 articulation (the scapulothoracic). The GH and AC joints are the most relevant in the practice of sports medicine. The AC joint has a limited range of motion and is stabilized by several ligaments and muscle attachments. (See Figure 1.)

Unlike the AC joint, the GH joint is designed for function and mobility rather than stability. The humeral head articulates with the shallow glenoid fossa of the scapula. The 3:1 humeral-head/glenoid-surface ratio allows this joint to enjoy the greatest mobility of any joint in the body. It is especially susceptible to dislocation.

Like the AC joint, the GH joint is stabilized by several ligaments and muscles. The subacromial space is defined superiorly by the coracoacromial arch and inferiorly by the greater tuberosity of the humerus. This space includes the rotator cuff tendon, the long head of the biceps, and the subacromial bursa. The rotator cuff includes the supraspinatus muscle, which helps abduct the arm; the teres minor and the infraspinatus (external rotators); and the subscapularis (internal rotator). The rotator cuff muscle complex serves as a humeral head depressor (it lowers the head in the glenoid).

The biceps muscle has a long head and a short head. The long head of the biceps tendon originates at the supraglenoid tubercle, exits the GH joint, and runs distally through the bicipital groove. The short head arises from the coracoid process. The long head and short head form 1 tendon distally that inserts into the bicipital tubercle of the radius. The biceps tendon provides flexion and supination of the elbow joint, and the long head of the biceps acts as an additional depressor of the humeral head.

**Table 1. Sports-Related Injury Sites**

<table>
<thead>
<tr>
<th>Sport</th>
<th>Injury site (most likely &gt; less likely)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseball and softball</td>
<td>shoulder &gt;&gt; elbow/forearm, wrist, fingers &gt; ankle, hip, back</td>
</tr>
<tr>
<td>Basketball and volleyball</td>
<td>ankle, knee &gt;&gt; hip/thigh &gt; Achilles tendon, heel, thigh, foot</td>
</tr>
<tr>
<td>Football</td>
<td>knee &gt; ankle &gt; head, shoulder, neck &gt; back, face, wrist/fingers</td>
</tr>
<tr>
<td>Hockey</td>
<td>head/neck &gt; ankle, knee, shoulder/arm &gt; eye, wrist/hand</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>shoulders &gt; torso/back/hip, wrist &gt; elbow &gt; ankle, head/neck</td>
</tr>
<tr>
<td>Roller-blading</td>
<td>distal forearm/wrist &gt; lower leg &gt; elbow &gt; knee &gt; head</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>wrist &gt; head &gt;&gt; upper extremity &gt; lower extremity</td>
</tr>
<tr>
<td>Snow skiing</td>
<td>lower extremity, leg/knee &gt;&gt; head &gt;&gt; thumb, shoulder, ankle</td>
</tr>
<tr>
<td>Soccer</td>
<td>knee/ankle &gt;&gt; shin/foot, hip/thigh &gt;&gt; shoulders, cervical spine, head</td>
</tr>
<tr>
<td>Swimming</td>
<td>shoulder &gt; knee &gt; elbow, head/spine (diving)</td>
</tr>
<tr>
<td>Wrestling</td>
<td>shoulder &gt;&gt; knee &gt;&gt; back/neck, foot/ankle, wrist/hand</td>
</tr>
</tbody>
</table>


Figure 1. Shoulder Anatomy

Schematic representation of the normal ligamentous attachments between the acromion and the coracoid process of the scapula and the clavicle.

History
As with most musculoskeletal injuries, the patient history is crucial. Many shoulder injuries occur in overhead athletic activities, such as baseball or basketball, and are chronic in nature. However, in the ED, patients often present with new traumatic injuries or with extreme exacerbations of chronic conditions. Historical factors relating to the sport—such as repetitive motion, conditioning, and requirements for that sport—are important considerations. Knowledge about the position of the arm at the time of injury, the degree of muscle contraction or relaxation, and the direction of momentum of the athlete help determine the type and severity of the injury. Also note any history of previous orthopedic procedures on the shoulder as well as any previous injury or dislocation.

Physical Examination
Examination of the shoulder should be performed with both of the shoulders completely exposed. Compare both sides, looking for asymmetry, bony deformities, and chronic muscular changes. It may help to palpate the opposite shoulder to determine the distinctive anatomy. Palpate the bones of the affected shoulder for tenderness, crepitus, and deformity. The rotator cuff muscles should be palpated along the muscle belly, tendon, and at the insertion at the greater tuberosity. Evaluate the AC joint for tenderness and asymmetry. The entire clavicle should also be examined. Note the active and passive ranges of motion of both the normal and affected shoulder.

A detailed neurovascular examination is very important with all shoulder injuries but especially with a proximal humerus fracture because of the proximity of the brachial plexus, axillary nerve, and vasculature. The axillary nerve supplies motor branches to the deltoid and teres minor and sensory fibers to the skin that overlies the lateral aspect of the upper arm. (Note: The “regiment’s band,” or upper lateral cutaneous nerve of the arm, is the more precise term for this sensory portion of the axillary nerve.) The tip of the shoulder is actually innervated by the supravacular nerve. Test and document both, especially with a suspected shoulder dislocation.

Diagnostic Testing
An optimal shoulder series includes 3 views: a true anterior-posterior (AP) (which unlike the standard AP projects the GH joint without bony overlap), transscapular lateral, and axillary lateral. Scapular views can be obtained if there is suspicion of a scapular fracture.

Which patients with a shoulder injury require radiographs? One prospective study of 206 patients with shoulder pain obtained radiographs on all patients, and 88% of the radiographs were deemed therapeutically uninformative.

Low-risk patients were then defined as:
- those with no fall and no swelling
- those with a fall but no swelling or pain at rest
- those with a fall and pain at rest but no swelling and normal range of motion

Another area of contention is whether pre- and postreduction radiographs are required in patients with clinically obvious and likely uncomplicated anterior shoulder dislocations. In 1 prospective study of 97 patients with possible shoulder dislocations, prereduction radiographs did not affect the management in any patients and added about 30 minutes to the treatment time. In a different retrospective study of 175 patients with shoulder dislocations, only 1 patient had a change in management dictated by the postreduction radiograph (a persistent dislocation). However, the studies to date have been small, and many believe that more data are needed before routine x-raying in such patients is discontinued. One argument for a prereduction radiograph involves identification of 2-part proximal humeral fracture-dislocations. These fracture-dislocations should never be reduced in the ED, because it is possible to dislocate the articular head from the humeral shaft, leading to permanent avascular necrosis.

It has been the standard of care to ionize patients with a presumed shoulder dislocation twice—to confirm the dislocation and rule out a fracture, as well as to obtain a postreduction radiograph to confirm relocation and ensure no fracture resulted from the reduction. As alluded to in the previous paragraph, the debate continues about the necessity of pre- and postreduction radiographs. Although the data accumulated to date seems to obviate the need for 2 radiographs, studies continue to be small and lack the desired power to change practice.

A 2007 article in the Journal of Emergency Medicine discussed examining postreduction radiographs to determine what information is added. In 40 patients with 16 total fractures, 37.5% of the fractures were seen only on postreduction radiographs, with the vast majority of the missed fractures being Hill-Sachs or Bankhard fractures. Postreduction radiographs confirmed all the reductions. Thus, sparing the patient from a postreduction radiograph will miss slightly more than one-third of the fractures associated with anterior shoulder dislocations; however, none of these are significant fractures that would change ED management.

We can conclude that all significant shoulder fractures will be seen on prereduction radiographs, clinicians do not need postreduction x-rays to confirm relocation, and reduction-caused fractures are rare and clinically insignificant if they do occur. We hope this will encourage emergency physicians to avoid postreduction radiographs and shorten the ED visit for the patient.
Clavicle Fracture
Clavicle fractures account for 5% of all fractures and result from a direct blow to the clavicle or a fall on an outstretched arm. The proximal fragment may be displaced upward by the action of the sternoclavicular and, deformity and crepitus may be palpable over the fracture site. Some experts maintain that all patients with pain, deformity, or crepitus require a chest radiograph, as some reports note that routine clavicle radiographs may miss fractures owing to the overlap of surrounding structures. The literature, however, provides no strong studies that prove the best approach to radiography. Although pneumothorax is a rare complication of clavicle fracture, a lung examination and a careful assessment of the x-ray for pneumothoraces are necessary.

Fractures of the middle third of the clavicle account for approximately 80% of all clavicular fractures and should be treated with shoulder sling immobilization and pain control. Until the late 1980s, the figure-of-eight clavicle strap was used to immobilize all middle-third clavicle fractures. The more comfortable simple sling has generally replaced this figure-of-eight strap, as randomized, controlled clinical trials show equivalent outcomes. The patient should be referred to an orthopedist or family physician experienced with these fractures.

Distal clavicle fractures often produce minimal deformity and may be confused with AC joint injury. Some types of distal clavicle fractures may require operative repair, so early referral to an orthopedist is useful. Proximal clavicle fractures are the least common and are difficult to diagnose because of bony overlap. Treatment is usually conservative.

Open clavicle fractures, posterior sternoclavicular dislocations, and fractures associated with a pneumothorax require urgent orthopedic and surgical consultation.

Glenoid Fractures
The classic mechanism of injury for a glenoid fracture involves falling onto the point of the shoulder with the arm adducted. An anterior shoulder dislocation may also fracture the glenoid (the so-called Bankart’s fracture). Symptoms of a glenoid fracture include pain, decreased range of motion, and, occasionally, deformity. Glenoid fractures may be associated with other injuries, such as rib fractures, pneumothorax, GH or AC shoulder dislocation, and nerve or tendon injury.

All glenoid fractures require urgent orthopedic consultation. In most cases, a CT scan of the shoulder is also necessary for treatment decisions (the timing of which may be deferred to the consultant).

Proximal Humerus Fractures
Athletes may suffer a proximal humerus fracture when a significant amount of force is transmitted to the humerus, such as a fall onto an outstretched, abducted arm. Symptoms of a proximal humerus fracture include pain, inability to move the arm, pain with passive range of motion, deformity, swelling, and discoloration. Once identified radiographically, further studies are generally not indicated.

The majority of simple, nondisplaced proximal humerus fractures can be treated conservatively with ED immobilization and referral. (Some simple, nondisplaced fractures can be managed by a primary care physician.) More than 80% of all proximal humerus fractures are nondisplaced and can be immobilized in a sling and swathe. Comminuted or multipart fractures usually require open reduction and internal fixation. Complications from a proximal humerus fracture include avascular necrosis of the humeral head, brachial plexus injury, frozen shoulder syndrome (adhesive capsulitis), and nonunion.

It seems that ultrasonography is plunging into every field of medicine, with orthopedics being no exception. Investigators have proven ultrasonography’s efficiency at evaluating patients with orthopedic fractures. The U.S. military published a study in 2008 that assessed the accuracy of ultrasonography versus x-ray to determine the success of fracture reduction. Ultrasonography accurately visualized 5 out of 5 successful reductions of hand fractures.

Although small, this study offers the possibility that soon malalignment will be seen before the cast has even set or patients will be discharged quicker with 1 less x-ray taken. If either becomes routine, this new imaging capability will have obvious applicability and beneficial effects on emergency medicine.

Emergency clinicians were the major players in another, larger study published in 2009, where they sonographed patients, assessing for the presence of orthopedic fractures. Ultrasonography yielded an overall sensitivity of 100% and a specificity of 94% for diagnosing fractures.

Although these studies were conducted to facilitate ultrasonography use in combat zones or remote regions, it seems a very natural progression into EDs, even though the x-ray machine is down the hallway.

AC Separation
The AC joint is often injured by a fall onto the outstretched hand or onto the point of the shoulder, one of the most common injuries among bicyclists. Symptoms include point tenderness on or around the joint, pain with movement (especially addition), swelling, deformity, and discoloration.

Although there is a 6-stage classification system of AC joint separation, most emergency clinicians are familiar with the 3-grade system. (See Figure 2.) Severity of injury may range from strains of the ligamentous complex with tenderness over the AC joint and normal radiograph findings to joint dislocation and clavicle displacement.
All suspected injuries to the AC joint should be x-rayed to exclude a distal clavicle fracture. Special AC views are best, as standard AP and axillary lateral views of the shoulder rotate the AC joint. Studies indicate that stress radiography views are low-yield and therefore are generally unnecessary. ED management is conservative regardless of grade of injury. Minor injuries can be treated with sling immobilization, nonsteroidal anti-inflammatory drugs (NSAIDs), ice, and relatively early mobilization. Grade III injuries require outpatient orthopedic referral and may benefit from operative intervention in selected patients.

**GH Dislocations**

More than half of all dislocations treated by the emergency clinician involve the GH joint. The GH joint may dislocate anteriorly, posteriorly, inferiorly, or superiorly. Anterior dislocations account for more than 95% of all shoulder dislocations. They are exceedingly common in contact sports, such as football, rugby, lacrosse, and wrestling. Posterior dislocations are rare and usually result from a seizure or electrical injury.

When the humeral head dissociates anteriorly from the glenoid fossa, it can rest under the inferior rim of the glenoid, beneath the coracoid process, and, less commonly, in an intrathoracic or subclavicular fashion. (See Figure 3, page 42.) The mechanism of injury for anterior dislocation is commonly abduction, extension, and external rotation. (Think of a football quarterback about to pass downfield who gets struck in the arm before starting the power portion of the throw.)

Patients complain of exquisite pain around the shoulder, and the shoulder is often held in external rotation and abduction. There is often a prominent acromion and depression of the area normally occupied by the humeral head, leading to a “squared off” deformity to the arm.

The axillary nerve supplies sensation to the skin that overlies the lateral aspect of the shoulder and motor innervation to the deltoid and teres minor muscle. Assess and document the status of the axillary nerve before and after reduction, as axillary nerve injury is seen in 5% to 54% of patients. Fortunately, nerve function usually returns with time. Athletes who sustain injury to the axillary nerve have variable prognosis for recovery, although return of function is typically good to excellent. Other neurovascular injuries include damage to the brachial plexus, radial nerve, and axillary artery. The most common bony deformity is a Hill-Sachs’s lesion; this involves indentation of the humeral head by the inferior glenoid or the coracoid process. Fracture of the greater tuberosity is also possible, and disruption of the rotator cuff can occur with inferior GH shoulder dislocations, especially in those older than age 40.

The incidence of nerve damage following shoulder dislocation or humeral neck fracture remains uncertain. In a study enlisting 101 patients with these injuries, 45% demonstrated electrophysiological nerve damage. The prevalence was much higher when the patients were older or when they also sustained a hematoma. Most had partial or complete recovery of nerve function within 4 months, and only 8 had residual motor loss. Nerve function deteriorates unless early detection is made that facilitates appropriate treatment. The study notes that the highest injury loss was seen in axillary nerves (37%) followed by suprascapular nerves (29%) and radial nerves (22%).

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**Figure 2. Acromioclavicular Separation Types**

- Type I (a): Ligamentous strain—no deformity, but tenderness of AC joint
- Type II (b): Rupture of acromioclavicular ligament—can have slight deformity on physical examination
- Type III (c): Rupture of both acromioclavicular and coracoclavicular ligament—significant deformity on physical examination, bottom of clavicle at or above top of acromion on x-ray

The electromyogram studies revealed that all of the lesions were due to axonal loss. The finding that hematomas increase the odds of nerve damage indicates the higher level of trauma to the neurovascular bundle in these patients. The study also reported that sensation loss did not have diagnostic significance, as motor lesions were not necessarily associated with sensory loss. Thus, patients for whom clinical assessment is difficult because of pain should be referred for electrophysiological evaluation to dictate early treatment. Practitioners should be highly suspicious of a nerve injury, because such a large percentage of patients develop this and early recognition is necessary to prevent residual neurological deficits.

Posterior shoulder dislocations comprise only 2% of all GH dislocations and are frequently missed. The injury may occur after a fall onto an outstretched hand with the arm in flexion, adduction, and internal rotation or from a direct blow to the anterior shoulder. On examination, abduction is severely limited and external rotation is blocked. The shoulder has a flattened, squared-off appearance with a prominent coracoid process. The humeral head may be palpated posteriorly. Standard radiograph results may appear deceptively normal. However, there are some signs that can be helpful when present. The “rim sign” refers to the increased distance between the anterior glenoid rim and the articular surface of the humeral head on a true AP view. There may be a loss of the elliptical overlap of the humeral head and the glenoid fossa or a “light bulb” appearance to the humeral head because the shoulder is internally rotated.

Inferior GH dislocation, also known as luxatio erecta, is rare but striking in its presentation. The classic presentation is an arm that is hyperabducted and locked above the head. The mechanism of injury is hyperabduction of the humerus, which then impinges on the acromion, causing a tear in the inferior GH capsule with disruption of the rotator cuff. Rarely, a violent force directly applied to the shoulder from above can produce this injury.

Obviously, all dislocations of the GH joint require reduction. There are several common and accepted methods of reducing GH shoulder dislocations. The vast majority of anterior dislocations can be reduced by the emergency clinician without orthopedic consultation. Although previous doctrine held that patients generally required conscious sedation before reduction attempts, new research indicates that this may not be necessary.

Several studies show that intraarticular lidocaine is an acceptable alternative to conscious sedation. Reduction success rates are statistically similar in the conscious sedation and intraarticular lidocaine groups. Intraarticular lidocaine is similarly effective in facilitating reduction and reducing pain but significantly shortens ED stays and reduces costs significantly. The procedure of intraarticular analgesia begins with prepping the shoulder with povidone-iodine. Inject 20 mL of 1% lidocaine via a long 20-gauge needle from just off the lateral edge of the acromion. Certain methods of reduction (such as scapular manipulation) require neither conscious sedation nor local anesthetics.

An Emergency Medicine 2007 study attempts to put the intraarticular lidocaine versus conscious sedation debate to rest by conducting a nonblind, randomized clinical trial. Mohrari initiated the project because of the conflicting literature on whether lidocaine offers the same pain relief as the intravenously injected narcotics and benzodiazepines. Prior studies championing intraarticular injection highlight that the reduction was comparatively easier. Moharari’s study, which enrolled 48 patients, revealed that lidocaine offered the same pain relief as intravenous meperidine and diazepam and resulted in fewer complications.

The drawback is lidocaine needs 15 minutes to take full effect, lengthening the duration of the procedure. Intraarticular infection is another rare event reported following lidocaine injections, but this study reported no such event. Although the reduction process took slightly longer with the lidocaine, the recovery period and time spent in the ED were considerably less. Fifty-eight percent of the intravenous group experienced complications as opposed to 13% in the intraarticular group. The complications in descending order of frequency were drowsiness, respiratory depression, hypotension, headache, nausea, and localized parathesias. Importantly, 5 people

**Figure 3. Types of Anterior Glenohumeral Dislocations**

A: subcoracoid; B: subglenoid; C: subclavicular; D: intrathoracic.

in the conscious sedation group required bag-valve-mask ventilation because of respiratory depression.

The traction-countertraction method of shoulder reduction involves an assistant who holds a sheet placed around the torso in the axilla and the emergency clinician placing traction on the affected limb. This can dislodge the humeral head from its resting position under the glenoid or coracoid. Quite a lot of traction is generally required to overpower the muscles and tendons that are maintaining the dislocated position. (See Figure 4.)

The Stimson method involves placing the patient prone with the dislocated limb hanging off a stretcher. A 10-pound (4.5 kg) weight is attached to the extremity and allowed to hang. As the muscles relax, the shoulder will autoreduce in about 20 minutes. (See Figure 5.)

The external rotation method involves gently and slowly externally rotating the shoulder and flexing the shoulder to 90°. This will reposition the humeral head about the glenoid or coracoid and generally cause reduction. An alternative technique involves adducting the shoulder so that the patient’s elbow is against his or her chest wall then slowly externally rotating the arm completely.

The Milch technique is similar to external rotation, but it involves hyperabduction first, then external rotation when the arm is fully hyperabducted, as if “picking an apple from a tree.” One study indicated that the Milch technique was easy to employ and had equal success rates when used by both junior and senior staff. Additionally, they found that 73% of patients who underwent shoulder reduction with this technique did not require any sedation.

Scapular manipulation involves having the patient lie prone with the affected arm hanging off the bed or having the patient sit up while an assistant applies forward traction to the arm. The emergency clinician uses one hand to rotate the inferior tip of the scapula medially while stabilizing the superior and medial edges with the other hand. (See Figure 6, p. 44.) Unlike the other techniques, scapular manipulation attempts to reposition the glenoid fossa rather than the humeral head. Studies show that the procedure is simple, and the reduction is accomplished in less than a minute in most cases. This technique may also reduce the need for premedication. McNamara demonstrated that no premedication was needed in 64% of patients whose shoulders were reduced with this technique.

A recently introduced technique for the reduction of anterior shoulder dislocations is the Spaso technique. To perform this reduction, place the patient in the prone position and gently grasp the wrist on the affected side. The limb should gently and slowly be elevated until it is vertical, then traction should be applied. While maintaining traction, the shoulder should be gently externally rotated. It may be necessary to palpate the humeral head and gently nudge it into the glenoid fossa. A recent article indicated that this technique is highly effective in reducing anterior shoulder dislocations and (in their study) induced no complications.

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**Figure 4. The Traction-Countertraction Reduction**

This is the safest and most effective method of reducing an anterior dislocation. If an assistant is unavailable to apply counter-traction, the sheet around the patient’s body can be attached to the stretcher.


**Figure 5. The Stimson Maneuver**

The patient lies prone with a weight attached to the wrist. The technique is easy to perform and comfortable for the patient. However, it is time-consuming.

Reduction of posterior dislocations involves axial traction with pressure on the humeral head and slow external rotation. Reduction of luxatio erecta is accomplished via traction applied in an upward and outward direction on the extended arm and countertraction applied across the top of the shoulder and chest wall in the opposite direction. Orthopedic consultation may be helpful.

It is very important to reassess the shoulder examination following successful reduction, as it is possible to injure the axillary nerve or fracture the humerus, glenoid, or other bony structure. Teens and young adults who dislocate their shoulder have a recurrence rate of 79% to 100% and must receive orthopedic follow-up. Patients should also receive appropriate analgesia and sling immobilization for 2 or 3 weeks. The duration of sling immobilization varies, but concerns over frozen shoulder have reduced the length in recent years. For most patients, 2 weeks followed by a rehabilitation program is suggested.

The debate continues about whether the management of shoulder dislocation should be changed. Historically, patients with shoulder dislocations were immobilized with a sling and underwent physical therapy. However, this treatment has led to an extremely high recurrence rate, with patients younger than 30 suffering the most. Surgical treatment offers both a lower recurrence rate and a higher level of function, which is significant in competitive sports but also applicable to the weekend warrior.

The current literature is still in conflict about whether certain maneuvers decrease the rate of recurrence. Cadaveric and clinical studies have proven that there are lower recurrence rates when the shoulder is immobilized in external rotation. But those results, like other nonsurgical methods, were not reproducible in other studies. There also continues to be no consensus regarding the duration of sling immobilization that is necessary to prevent or reduce repeated shoulder dislocations.

A 2007 study analyzing the management of shoulder dislocations found that the duration of immobilization had no impact on the rate of recurrence. It also revealed that the younger the patient on a first-time dislocation, the higher the likelihood of a recurrence. Patients who were between 14 and 20 years of age when they first suffered a dislocation had an 89% chance of recurrence, whereas patients whose first-time dislocation occurred when they were between 21 and 30 years of age had a recurrence rate of 70%. When a first-time dislocation occurred in a patient older than 30, the rate dropped dramatically to 30% to 40%. Interestingly, men had a 57% rate of recurrence compared with women, at 42%.

Emergency clinicians used Hippocrates’ method for reduction for 70% of the patients and Milch’s procedure for 30%; the success rates were 90% and 67%, respectively. Hippocrates’ method was found to be more effective in relocation of the humeral head but unfortunately was more painful and required 2 people to properly perform the maneuver.

There has been a trend over the past decade or so to surgically correct shoulder dislocations in younger patients to prevent repeated episodes and to enhance function. A prospective study of 46 young athletes revealed that there was only a 4% recurrence rate in a surgical group versus a 95% recurrence rate in the nonsurgical group. This finding should encourage all emergency clinicians to recommend a definitive surgical procedure to all younger patients presenting with shoulder dislocations; this would benefit the patient as well as reduce the workload for other practitioners.

**Rotator Cuff Injuries**

The rotator cuff muscles play an important role in virtually every sport, but are absolutely crucial to the overhead athlete. Participants in tennis, basketball, volleyball, and baseball frequently experience rotator cuff injuries.

Acute injury of the rotator cuff is marked by a sudden tearing sensation in the shoulder followed by severe pain radiating to the arm. The pain is often poorly localized but may be present at the insertion of the rotator cuff tendon along the midsubstances of the rotator cuff muscles or may radiate up to the

---

**Figure 6. Scapular Manipulation**

Proper hand positioning and direction of rotation during shoulder relocation using the scapular manipulation technique.

neck or down to the arm. Subjective weakness of the shoulder muscles as well as history of recurrent dislocations may be present. A severe tear of the rotator cuff is uncommon. Neer proposed that 95% of rotator cuff tears are related to chronic impingement of the rotator cuff between the humeral head and the coracoacromial arch.\(^{35}\) It can result from falling on an outstretched arm. Typically, tears are chronic and result from progressive degeneration.\(^ {36}\)

Litaker et al identified 3 components of the physical examination that can identify rotator cuff tears. These include supra- and infraspinatus atrophy, weakness with elevation or external rotation of the shoulder, and the impingement sign.\(^ {37}\) Impingement refers to inflammatory changes due to repetitive compression of the rotator cuff and associated structures between the humeral head and coracoacromial arch.\(^ {36}\) Neer’s impingement test involves moving the patient’s straightened arm to full abduction. Hawkins’ impingement test involves positioning the patient’s arm in 90\(^{\circ}\) of abduction and 90\(^{\circ}\) of elbow flexion then rotating the arm inwardly across the patient’s body. Pain reproduced by either one of these maneuvers is considered an impingement sign.\(^ {36}\)

Radiographs may exclude bony problems such as thick acromion, bone spur, glenoid erosions, and Hill-Sach’s lesions. Although the radiographs may show evidence of degeneration, the hallmark of a complete tear of the rotator cuff complex is superior displacement of the humeral head that is best seen in the externally rotated AP view.\(^ {4}\) Other imaging techniques, such as magnetic resonance imaging (MRI) or arthrogram, should be reserved for outpatient evaluation.

Severe tears should be immobilized in a sling, and patients should be referred for prompt orthopedic evaluation. Unless otherwise indicated, most patients should be started on NSAID therapy. Many require narcotic analgesia. Rest, avoidance of painful activities and positions, and orthopedic referral are important. It is usually not possible or necessary to differentiate among a severe tear, a chronic tear, or a flare of rotator cuff tendinitis in the ED. Patients with these should be treated in the same manner and given timely referral.

**Biceps Tendinitis**

In pitchers, weight lifters, and other athletes, the long biceps tendon may become inflamed. Symptoms of biceps tendinitis include pain with shoulder extension or elbow flexion, pain when trying to reach into the back pocket, and pain around the anterior shoulder. On physical examination, palpation of the tendon within the bicipital groove reproduces the pain, as does forearm supination.

Treatment of biceps tendinitis is similar to other overuse syndromes. Most patients should be prescribed oral NSAID therapy. Athletes should be encouraged to rest, ice, and avoid painful movements and positions. Orthopedic referral is appropriate in most patients if symptoms persist.\(^ {38,39}\)

### ED Evaluation: Hand Injuries

#### History And Physical Examination

The patient history should include the position of the hand at the time of injury, mechanism of injury, previous hand injuries, occupation, and hand dominance. Physical examination should assess for tenderness, tendon integrity, joint stability, range of motion, 2-point sensation, capillary refill, and motor function.\(^ {40}\)

#### Mallet Finger

Mallet finger (also known as baseball finger) is a rupture of the extensor tendon that attaches to the dorsal side of the distal phalanx of the finger. This tendinous injury occurs when there is a forced flexion of a fully extended finger, commonly involving a baseball or volleyball striking the tip. This forced flexion can cause a rupture of the extensor tendon or an avulsion of the bone at the tendon insertion. With the extensor mechanism disrupted, the patient will be unable to fully extend the distal phalanx, although passive extension will be possible.

Although the physical examination will be diagnostic, a radiograph should be obtained to rule out an associated avulsion fracture of the distal phalanx. Treatment is conservative and involves immobilizing the joint in an extension splint in a neutral position (some recommend slight hyperextension) for 6 to 8 weeks. The patient should be referred to a hand specialist for follow-up.

#### Jersey Finger

Jersey finger, or a tear of the flexor digitorum profundus, is essentially the opposite of mallet finger, as there is a forced extension of the finger during an effort to actively flex the digit. The classic description is that of a football player trying to grab an opponent’s jersey as the opponent is running downfield. The physical examination, again, is diagnostic, as the patient is unable to flex the distal phalanx at the distal interphalangeal joint. Radiographs should be obtained to rule out an associated avulsion fracture of the distal phalanx.

Jersey finger is usually managed operatively within 14 days of the injury. The finger should be splinted with the finger and wrist flexed, and the patient should be urgently referred to a hand specialist.

#### Gamekeeper’s Thumb

Gamekeeper’s thumb, also known as skier’s thumb (because skiing is now more common than twisting off the heads of rabbits), refers to injury of the ulnar
collateral ligament (UCL) of the thumb’s metacarpal phalangeal joint. On examination, there is tenderness over the ulnar side of the joint and weakness of pinch. Valgus stress testing of the thumb UCL should be done both in full extension and in 30° of flexion. Greater than 35° of joint laxity or 15° more laxity than the contralateral side UCL indicates a complete UCL rupture.4,41

Radiographs should be obtained before stressing the joint to exclude associated avulsion or condylar fractures. Treatment of a partial UCL rupture involves immobilization in a thumb spica cast for 4 weeks. Complete tears require a surgical procedure. All patients with this injury suspected should be immobilized and referred to an orthopedist, as underdiagnosis can lead to chronic disability.4

**ED Evaluation: Selected Neurologic Injuries**

Although a full discussion of neurologic sports injuries is beyond the scope of this chapter, the August 2005 issue of *Emergency Medicine Practice* “Mild Traumatic Brain Injury: What To Do When There is Nothing (Obviously) Wrong,” provides an excellent overview. For a complete discussion of cervical spine injuries, see the October 2001 issue of *Emergency Medicine Practice*, “Cervical Spine Injury: A State-Of-The-Art Approach to Assessment and Management,” and the April 2009 issue of *Emergency Medicine Practice*, “An Evidence-Based Evaluation Of The Patient With Blunt Cervical Trauma.”

**Brachial Plexus Injuries**

Brachial plexus injuries are common in contact sports, especially football and rugby. A “stinger” or “burner” is classically defined as unilateral burning dysesthesias from the shoulder to the hand, with occasional weakness or numbness in the C5 and C6 distribution.42 The mechanism of injury is usually sudden forced flexion forward or laterally of the cervical spine, resulting in a stretch injury, presumably to the sixth cervical spinal nerve root.

For the vast majority of brachial plexus injuries, the consequences of cervical root strains are minimal. Patients experience pain, numbness, and tingling of the extremity opposite to the direction of lateral bending (ie, if the head is forced to the left side, the right arm will be affected). Rarely, there can be more severe damage to the nerves. The symptoms typically last minutes but can persist for days to weeks. The unilaterality, brevity, and pain-free range of motion in the athlete can assist in discriminating between a “stinger” and a cervical cord injury.42

Neck pain is usually not a prominent feature in traction injuries.43

ED examination of brachial plexus injuries should include a thorough neurological examination. Compare the strength and sensation with the nonaffected side. Additionally, examine the cervical spine and image when indicated. (See the October 2001 issue of *Emergency Medicine Practice.*) MRI is reserved for patients in whom a cervical spinal cord injury cannot be excluded or an as outpatient test for those with persistent symptoms.43

Rest and NSAID therapy may be helpful. Patients should have a thorough and normal neurological examination before resuming athletic activities. Some may benefit from a short course of physical therapy.43,44

**Transient Quadriplegia**

Transient quadriplegia most frequently occurs with an axial load injury to the cervical spine or after hyperextension or hyperflexion.45 Typically, the patient experiences transient upper and lower extremity paralysis and numbness that resolves over a period of minutes. The results of plain radiographs and computed tomography of the spine, as well as MRI of the spine, are usually normal (but still may be indicated depending on the clinical circumstances, such as cervical spine tenderness). Before the athlete is allowed to return to play, spinal stenosis must be ruled out, because this is an absolute contraindication for return to training.45 Cervical spinal stenosis can increase the risk of permanent neurologic injury.46,47

**ED Evaluation: Elbow Injuries**

**Elbow Dislocation**

The elbow is second only to the shoulder as the major joint most frequently dislocated. Football players and other contact sports participants are particularly vulnerable. Most dislocations are posterior, although the elbow may also dislocate medially, laterally, or anteriorly. (See Figure 7.)4,46

The classic mechanism of injury is a fall onto the outstretched hand with the elbow extended. Patients will have a marked deformity on the injured side and a prominent olecranon. They often maintain the elbow in about 45° of flexion.

Frequent neurovascular examinations are crucial. The median nerve and brachial artery are at particular risk. Brachial artery injury is noted in 5% to 13% of patients.49 Nerve and vascular injury after reduction have been reported.49,50 Treatment is prompt reduction. If the neurovascular status of the extremity is compromised, immediately reduce the elbow. Reduction of a posterior dislocation is accomplished by stabilization of the humerus and gentle traction of the wrist with flexion of the elbow if the joint does not easily reduce. In most cases, elbow reduction is uneventful.

Most patients will require conscious sedation or intraarticular anesthesia. Obtain postreduction radiographs and range the elbow through flexion and
extension to ensure stability. Immobilize the elbow in 90° of flexion. Phone consultation with an orthopedist may be helpful, because the stability of reduction and neurovascular status of the elbow must be closely monitored, especially for development of a forearm compartment syndrome. Most patients who dislocate their elbow without comorbid fractures have an excellent long-term prognosis.

ED Evaluation: Hip Injuries

Anatomy
The hip is a ball-and-socket joint that consists of the acetabulum and the proximal femur 2 to 3 inches below the lesser trochanter. There is a strong fibrous capsule surrounding the joint.

Overview
Severe hip pain in athletes is almost always the result of a strain or musculotendinous injury. In children and adolescents, these injuries are often avulsion fractures involving the iliac crest, anterior superior and inferior iliac spines, and lesser trochanter or ischial tuberosity. Hip fractures and dislocations are uncommon in sports activities and usually occur as a result of a high-speed collision.41

Avulsion fractures, such as avulsion of the anterior superior iliac spine, are the result of sudden, forceful contraction of the sartorius muscle. This fracture is usually seen in children and adolescents before the physis closes. The same mechanism in adults results in a strain instead of a fracture.

History And Physical Examination
As with any injury, the surrounding events should be noted. Determine the position the leg was in when the injury occurred, whether there was a pop heard or felt, and whether the patient could ambulate or resume play immediately after the injury. True hip joint pain often localizes to the groin. Examine the involved leg for deformity, shortening, rotation, and ecchymoses. Active and passive range of motion should be evaluated as long as the emergency clinician is reasonably sure there is no fracture or dislocation present. Look for tenderness of the iliac crest, pubic rami, or ischial rami. Hip pain with weight bearing despite no positive findings on radiographs may indicate an occult fracture of the joint.

Musculotendinous injuries around the hip are usually the result of an actively contracting muscle that encounters abrupt resistance. This is most commonly seen in track and field but can occur in any sport that involves rapid acceleration and deceleration, such as soccer or missing a kick in football.

Symptoms include a pop or snap and sudden, severe localized pain and immediate disability. Walking is difficult or impossible. The site of the injury is tender, and swelling is variable. The muscle is usually tense. Suspect an avulsion fracture if there is tenderness on palpation at any of the tendon insertions.

Muscular injury is frequently encountered in the 3 major muscle groups of the leg: the hamstrings, quadriceps, and the iliopsoas. Strain of the hamstrings is common with running and sudden acceleration. The patient develops sudden and severe pain in the posterior thigh. Range of motion of the hip is painful, and no bony tenderness is present. Treatment involves crutches with toe-touch weight bearing (only the toes bear weight) as tolerated.

The quadriceps are the most common muscular groups to suffer complete tears. When the muscles are contracted suddenly against the body’s weight, such as stumbling to prevent a fall, the quadriceps can suffer various degrees of tearing. On examination, there is pain with passive and active knee extension; with a complete tear, active knee extension against gravity is impossible. Treatment consists of weight-bearing with crutches.

Injury of the iliopsoas is commonly seen in gymnasts and dancers and is the result of sudden, forceful hip flexion against resistance. There is sudden, severe pain in the groin, thigh, or low back. There may also be abdominal pain at the origin of the iliopsoas. On examination, the groin is tender to palpation and there is pain with active hip range of motion. Radiographs of the femur should be obtained to exclude a fracture of the lesser trochanter. Treatment is bed rest for 7 to 10 days with partial flexion at the knee and hip.4

With most muscular injuries, complete the eval-
uation with a pelvic or hip radiograph to exclude associated avulsion fractures. The standard treatment of compression and ice is difficult to accomplish in the hip. Ambulation with crutches and bed rest are recommended. As with other musculotendinous injuries, active and isometric stretching should be started in 48 hours.

A contusion of the iliac crest is also known as a hip pointer. The iliac crest is very vulnerable to direct blows due to its poor protection. This injury may result in severe disability because the iliac crest serves as an anchor for abdominal and hip musculature. The history is significant for a direct blow to the hip, such as from a football helmet or fall onto a hard surface (which is common in soccer, football, and ice hockey). This painful blow is instantly disabling. On examination, the iliac crest is tender and there is a variable amount of swelling. The abdomen is often rigid because of abdominal wall spasm.

Radiographic evaluation of the pelvis may reveal a compression fracture. Consider intraabdominal injury in the presence of significant abdominal tenderness. In addition to ice and analgesics, a 6- to 8-day steroid burst may reduce the duration of disability.

**ED Evaluation: Thigh Injuries**

**Quadriceps Tendon Rupture**

Quadriceps (or extensor tendon) rupture results from powerful muscle contractions secondary to a fall or in conjunction with severe ligamentous disruption at the knee. This is typically an injury seen in older patients, but it may occur in younger patients involved in jumping activities. In athletes, the rupture most often occurs in high-power sports events, such as the high jump, basketball, and weightlifting. Patients report hearing a loud pop and are immediately unable to extend the leg or bear weight. They may complain of buckling of the knees or inability to walk up stairs or up an incline. Often there is a palpable soft tissue defect proximal to the superior pole of the patella, but this may be obscured by edema. All patients have marked weakness of the knee extensors, and most have an inability to perform a straight leg raise test when supine. Radiographs of the knee may reveal a poorly defined suprapatellar mass, an obliterated quadriceps tendon, and a joint effusion. Early diagnosis is important, as surgical repair within 48 to 72 hours is necessary to preserve the extensor mechanism of the knee.

**ED Evaluation: Knee Injuries**

There are 1.3 million visits to U.S. EDs because of knee trauma each year. Knee injuries produced by recreational sports tend to follow a different pattern than other mechanisms of casual injuries. In 1 study of 208 males who underwent knee arthroscopy after trauma, a significantly greater number of anterior cruciate ligament (ACL) tears were associated with sports activity (P = 0.032). Sports injuries also resulted in a significantly greater number of meniscal injuries (P = 0.028), whereas sedentary patients had a greater number of osteochondral fractures (10%) than the sports group (5%).

### Anatomy

The knee (see Figure 8) is a complex diarthrodial hinged joint that is frequently injured during sports activities. The knee is positioned between the 2 longest bones in the body—the femur and the tibia—but has minimal bony stability. There are 3 primary articulations within the joint complex. The patellofemoral articulation involves the patella and the distal femur, whereas the other 2 articulations involve the distal femur and the proximal tibia. The nonbony elements include 2 menisci, 4 ligaments (medial and lateral collateral ligaments and the anterior and posterior cruciate ligaments), and the surrounding capsule. The fibrocartilaginous menisci distribute weight and stabilize the knee. The medial meniscus is injured more frequently than the lateral meniscus.

The medial and lateral collateral ligaments resist valgus and varus stress, respectively. The anterior and posterior cruciate ligaments resist anterior and posterior stress and are the major stabilizing ligaments of the knee. The ACL is ruptured more often.

Figure 8. Knee Anatomy

Reproduced with permission from: Anderson MK, Hall SJ. Sports Injury Management. Baltimore: Williams & Wilkins; 1995:271. Figure 81C.
History
A careful history is often needed to ascertain the severity of the injury, as chronic overuse injuries can present with severe exacerbations (see Tables 2 and 3). An audible pop at the time of the injury and immediate swelling suggest a significant internal derangement. Sudden onset of a large effusion suggests an ACL injury. Note the patient’s ability to ambulate immediately following the injury and the position of the leg at the time of injury. For example, a football player tackled from the side while his foot is planted is at risk for a medial collateral ligament injury. It is especially important to consider the hip as a source of referred knee pain. Determine any previous knee injuries, any knee surgical procedure, and the functional status before injury.

Physical Examination
The examination begins with an inspection of the entire limb for deformity, bruising, and swelling. (See Table 4.) Comparison to the opposite leg is helpful. Palpate for localized tenderness, beginning in the nonpainful areas. The knee’s active and passive range of motion, within the limits of pain, should be tested next. It is important to specifically test the knee extension against gravity to ensure integrity of the extensor mechanism (quadriceps, patella, and patellar tendon). Specific tests are then performed to evaluate the mechanical integrity of the components of the knee joint. Obtain radiographs before stressing the knee if a fracture is likely.

Ligamentous injuries of the knee usually occur as a result of hyperextension or abnormal rotation. Identifying an internal derangement is more important than identifying the specific injury.

A recent literature review compared physical examination with either MRI or arthroscopy for meniscal or ligamentous injuries of the knee. Although there were limitations in the data, the authors found the Lachman test excellent for both ruling in and ruling out a tear of the ACL. The anterior drawer test was not particularly useful under any conditions, and there is no reliable examination for meniscal injuries. Potentially useful physical findings include alignment during standing or walking, active and passive range of motion, the presence of effusion, joint line tenderness, and the Lachman test. However, the general examination of the meniscus was not very informative, with a sensitivity of 77% and specificity of 91%. The Lachman test had a sensitivity of 84%, a specificity of 100%, a positive likelihood ratio of 42, and a negative likelihood ratio of 0.1 compared with joint line tenderness with a sensitivity of 84%, a specificity of 100%, a positive likelihood ratio of 82% and specificity (94%) of the complete physical examination of the ACL.

However, the general examination of the meniscus was not very informative, with a sensitivity of 77% and specificity of 91%. The Lachman test had a sensitivity of 84%, a specificity of 100%, a positive likelihood ratio of 42, and a negative likelihood ratio of 0.1 compared with joint line tenderness with a sensitivity of 79%, specificity of 15%, a positive likelihood ratio of 0.9, and a negative likelihood ratio of 0.1.

<table>
<thead>
<tr>
<th>Table 2. Differential Diagnosis Of Acute Traumatic Knee Pain</th>
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<tbody>
<tr>
<td><strong>Most serious</strong></td>
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<tr>
<td>· Knee dislocation</td>
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<tr>
<td>· Fracture of distal femur, patella, proximal tibia, or fibula</td>
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<tr>
<td>· Patellar or quadriceps tendon rupture</td>
</tr>
<tr>
<td>· Meniscal injuries</td>
</tr>
<tr>
<td>· Ligamentous injuries</td>
</tr>
<tr>
<td><strong>Most common</strong></td>
</tr>
<tr>
<td>· Sprains/strains</td>
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<tr>
<td>· Contusions</td>
</tr>
<tr>
<td>· Patellar dislocation or subluxation</td>
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<tr>
<th>Table 3. Significant Historical Points In Knee Injuries</th>
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<tr>
<td>· Acute onset of pain within 72 hours of injury</td>
</tr>
<tr>
<td>· Audible pop and immediate swelling with twisting or forced hyperextension</td>
</tr>
<tr>
<td>· Direct blow to anterior tibia, forced hyperextension, or axial load</td>
</tr>
<tr>
<td>· Direct blow to the medial or lateral aspect of the knee</td>
</tr>
<tr>
<td>· Varus or valgus stress to knee</td>
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<tr>
<td>· Twisting injury—painful popping and catching, delayed swelling</td>
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<tr>
<td>· Direct blow to patella or hyperflexion</td>
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<td>· Prior knee surgery</td>
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<tr>
<th>Table 4. Significant Physical Examination Findings In Knee Injuries</th>
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<tr>
<td>· Effusion or acute swelling</td>
</tr>
<tr>
<td>· Positive Lachman test</td>
</tr>
<tr>
<td>· Patellar tenderness or abnormal position</td>
</tr>
<tr>
<td>· Tenderness of the lateral or medial aspect of the knee or head of fibula</td>
</tr>
<tr>
<td>· Joint line tenderness or positive McMurray’s test</td>
</tr>
<tr>
<td>· Inability to straighten or flex the knee greater than 90°</td>
</tr>
<tr>
<td>· Inability to perform straight-leg raise</td>
</tr>
<tr>
<td>· Positive posterior drawer test</td>
</tr>
<tr>
<td>· Valgus or varus joint instability</td>
</tr>
<tr>
<td>· Inability to bear weight for four steps without assistance</td>
</tr>
</tbody>
</table>

1. Strayer offers the critique that the participants in the JAMA article were examined by orthopedists who conduct many more knee examinations than do emergency clinicians and the participants complained of chronic knee pain that is easier to manipulate than the acute injuries seen in the ED.

Both of these factors limit the applicability of this study to ED management. The review article concludes that no single physical examination maneuver can reliably guide treatment of potentially injured ligaments or menisci, but a comprehensive physical examination performed by an experienced emergency clinician should be able to affect management in those patients who can withstand an adequate physical examination. The emergency medicine review recommends a low threshold for orthopedic referral because of the aforementioned limitations.

Physical Examination Maneuvers
The value of any of these maneuvers is best determined by comparison to the uninjured knee, as abnormalities may be subtle.

The collateral ligament stress test tests the integrity of the medial and lateral collateral ligaments. Injuries to the medial collateral ligament are based on the amount of laxity present. The knee should be tested by applying a valgus stress in full extension and 30° of knee flexion. A grade I injury has 0 to 5 mm of laxity, a grade II injury has 5 to 10 mm of laxity, and a grade III injury, which means complete ligamentous disruption, has greater than 10 mm of laxity. When the knee is tested in full extension, any laxity with valgus stress implies complete medial collateral ligament disruption. Injury to the lateral collateral ligament, which is uncommon, is tested by applying a varus force to the knee in extension and 30° of flexion. Lateral laxity of more than 10 mm without a firm endpoint reflects complete lateral collateral ligament rupture, whereas less than 10 mm of laxity suggests a partial tear. Whenever testing laxity, compare with the uninjured knee, as some patients have considerable normal laxity.

The Lachman test evaluates the ACL and is the single best clinical test for determining the integrity of the ACL. It is also one of the only reliable tests in a patient with a severe hemarthrosis. Have the patient lie supine and flex the knee to 20° to 30°. The examiner stabilizes the femur with one hand and pulls the tibia forward with the other hand while estimating the amount of anterior movement. A distinct endpoint at which forward displacement stops suggests that the ACL is intact. The anterior drawer test is much less reliable than the Lachman test for evaluating the ACL (70% vs. 99% accuracy in 1 study) and should not be used. (See Figure 9.)

The posterior drawer test is the criterion standard used to evaluate the posterior cruciate ligament. The examiner flexes the patient’s knee to 90°, anchors the thigh, and pushes the tibia backward. The location of the anterior proximal tibia in relation to the patella and femoral proximal tibia is used to estimate the posterior movement of the tibia on the femur. Positive test results when the tibia moves posterior to the femoral condyles. A blinded, randomized, controlled study of 39 patients showed it to be 96% accurate, 90% sensitive, and 99% specific. (The examiners in this study, however, were orthopedic surgeons trained in sports medicine.)

The McMurray test evaluates the menisci. The examiner grasps the lower leg and flexes and extends the knee while internally and externally rotating the tibia on the femur. The other hand is used to palpate the knee for a clicking sensation, which constitutes a positive finding. It is also considered significant if the patient experiences pain during internal and external rotation. This test is not specific for meniscal problems, as it also detects soft tissue injuries.

The apprehension sign is used to diagnose a partial dislocation (subluxation) of the patella or recent patellar dislocation that has spontaneously reduced. This sign describes the anxiety exhibited by the patient as the examiner attempts to slide the patella laterally, which results in pain and forceful contraction of the quadriceps femoris muscle.

Knee Radiography
More than $1 billion is spent on emergency radiography of the knee each year in the United States, with 90% to 92% of these studies showing no fracture. A standard knee series includes the AP, lateral, and, in most hospitals, oblique views. These radiographs...
Clinical Pathway: Evaluation Of Knee Injuries

Knee pain after an injury

Evaluate for Ottawa criteria
Radiographs recommended if any of the following are met:
• the patient is 55 years or older
• there is tenderness at the head of the fibula
• there is isolated tenderness of the patella
• the patient is unable to flex the knee to 90°
• the patient is unable to take four steps both at the time of the injury and at the time of the evaluation (Class II)

Possible knee dislocation

None present

One or more present

Obtain radiograph (Class II)

Hard signs of vascular injury?
• active hemorrhage
• expanding hematoma
• absent pulse
• distal ischemia
• bruit/thrill over the popliteal artery

Reduce immediately (Class I)

Obtain radiograph; then reduce if dislocated (Class I)

Neurovascular deficits?

YES

NO

Immediate orthopedic and vascular surgery consult; consider angiography (Class II)

Consult orthopedics and admit to hospital; consider ankle/brachial pressure ratio—if < 0.8, consider angiography (Class III)

NO

Treat and refer
• Treat as indicated
• Orthopedics referral (Class I)

 Findings of ligamentous instability?

Treat
• Arthrocentesis (Class III)
• RICE (Class II)
• Knee immobilizer/crutches (Class II)
• NSAIDs (Class II)
• Orthopedics referral (Class I)

For Class of Evidence Definitions, see page 1.
should be examined for loose bodies, osteochondral injuries, and avulsion fractures. Additional views, such as a “sunrise” view or “tunnel” view, are sometimes needed. A sunrise view is a tangential view that provides good visualization of the patella and patellofemoral joint. A tunnel view images the intercondylar notch and detects tibial spine fractures and loose bodies within the notch.4

Clinical decision rules such as the Ottawa or Pittsburgh knee rules are a cost-effective way to improve radiograph use. The Ottawa rules were developed from a prospective evaluation of 23 clinical indicators in 1047 adult patients with knee injuries.66 The Ottawa knee rules, which have been validated by numerous other investigators,67,68 recommend radiographs if any of the following conditions are met:69
• the patient is 55 years or older
• there is tenderness at the head of the fibula
• there is isolated tenderness of the patella
• the patient is unable to flex the knee to 90°
• the patient is unable to take 4 steps both at the time of the injury and at the time of the evaluation

A study of 1522 adults designed to validate the Ottawa knee rules found the sensitivity for detecting clinically important fractures to be 100%.67 Like all decision rules, the Ottawa knee rule has its limitations. The rule was not designed to apply to patients younger than 18 years, pregnant patients, patients with isolated skin injuries, patients with injuries more than 7 days old, patients with altered level of consciousness, or patients who have multiple injuries.70 The Ottawa definition for ambulation is also quite liberal, with any minimal foot transfer, including severe limping, considered as “able to bear weight.”70

Although the Ottawa knee rules were not originally intended for the pediatric population, a recent study evaluated its applicability in children. In a prospective study of 234 patients 2 to 18 years old, the rule reduced the need for radiography but only had a sensitivity of 92% for detecting fractures.71

Another clinical decision rule, developed at the University of Pittsburgh, uses different criteria. The Pittsburgh rules were designed using a retrospective review of 11 clinical indicators in 201 patients with knee injuries. The Pittsburgh knee rules recommend radiography in the following circumstances:70
• a fall or blunt trauma in patients older than 50 or younger than 12
• a fall or blunt trauma with the inability to walk 4 steps in the ED

A prospective study of 934 patients found that the Pittsburgh knee rules outperformed the Ottawa knee rules. In the 745 patients in whom the Pittsburgh rules were applied, the sensitivity was 99% and the specificity was 60%. The Ottawa rules were applied in 750 patients and demonstrated a sensitivity of 97% with a specificity of only 27%.70

Magnetic Resonance Imaging
MRI is the imaging modality of choice to diagnose significant acute and chronic soft tissue injuries of the knee. However, at the present time MRI is costly and has limited availability. Because the definitive evaluation of these injuries is rarely necessary on an emergent basis, the use of MRI is best deferred to the consultant.

 ACL Injuries
The ACL is the most frequently injured major ligament in the knee and is frequently torn in skiing and contact sports, most commonly football.4 The ACL is injured during recovery from falling backward (in expert skiers) or hyperflexion and internal rotation of the knee (in lower level skiers).72 This injury can also occur in basketball players when the hyperextended knee is twisted or when the patient collides with another player. An audible pop, immediate swelling, and inability to continue the activity mark this injury. The Lachman test is diagnostic.49

Collateral Ligament Injuries
The medial collateral ligament is a medial stabilizer of the knee and is most commonly injured by a blow to the lateral aspect of the knee or by the patient planting the foot and then colliding with another athlete.69 Patients usually report hearing a pop at the time of the injury, although this finding is not specific. There is often an associated ACL injury as well. A first- or second-degree sprain will have tenderness, usually at the medial femoral epicondyle. Swelling will occur quickly, but bruising is often delayed 24 to 36 hours. A third-degree sprain may not cause severe pain, but the patient cannot continue the activity after the injury, limps, and cannot fully extend the leg.69 The degree of injury can be estimated by the amount of joint line opening. An isolated tear usually heals without surgical intervention.

Injury of the lateral collateral ligament is less common but more disabling. It occurs via hyperextension with varus stress or from a direct blow or rotation.

Posterior Cruciate Ligament Injuries
Injury to this ligament is less common than to the ACL because of the strength of the ligament. It is usually caused by a direct blow to the anterior tibia or a fall. The posterior drawer test is diagnostic, and treatment is conservative.

Meniscal Injuries
The menisci are often co-injured with other structures, usually as a result of a twisting motion to a flexed knee. Unlike collateral ligament injuries,
pain with meniscal injury is usually worse with weight bearing. The classic clinical triad is joint line pain, swelling, and locking. On examination, there is tenderness and effusion along the medial or lateral joint lines and pain in the posterior aspect of the knee on passive extension and flexion. There may be locking immediately after the injury because of a displaced meniscal fragment. A McMurray test exhibiting a positive finding is helpful in the diagnosis, but a negative result does not exclude injury. Evaluate for a locked knee, where the knee becomes fixed in flexion due to a mechanical block from the displaced cartilage.

In 2008, British investigators conducted a prospective study using ultrasonography to assess menisci compared with MRI. MRIs are costly, much less accessible, and significantly longer examinations compared with ultrasonography. Ultrasonography revealed a sensitivity of 86% and a specificity of 69% at assessing meniscal tears compared with MRIs.

Although ultrasonography matched the sensitivity of MRI, the number of false-positives was remarkably higher. Thus, the technique will need to be improved to become clinically useful, especially in the ED.

**Disposition Of Ligamentous And Meniscal Injuries**

The definitive treatment of ligamentous and meniscal injuries is not emergent. Patients are to be immobilized, instructed to elevate the leg, and referred to an orthopedist in 2 to 4 days. The exception is the severely locked knee, in which case the orthopedist should be consulted while the patient is in the ED.

**Knee Dislocation**

Despite its dense protective shell of 11 cruciate and collateral ligaments and tendons, significant blunt forces can cause subluxation of the tibia over the femur, causing dislocation of the knee. This often occurs as a result of a high-speed motor vehicle accident, but it can also occur during a sports activity, such as football, waterskiing, or skateboarding. Knee dislocations are classified according to the direction that the tibia is displaced in relation to the femur. Of knee dislocations, 50% to 60% are anterior, but popliteal artery injury is most commonly associated with posterior dislocations. The prevalence of popliteal artery injury in association with knee dislocations varies from 21% to 80%. The risk of vascular injury appears to be less when the dislocation is relatively low energy, such as those associated with athletic events.

There is a high incidence of spontaneous reduction of a dislocated knee before ED evaluation, and the evaluating emergency clinician must maintain a high index of suspicion for this injury. The patient may give a history of the knee popping out and then popping back into place. On examination, the knee is usually grossly swollen, painful, and unstable. Sometimes with complete disruption of the joint capsule, the hematoma leaks into the thigh or calf and the knee is almost normal in size. Results of the vascular examination may be normal or show signs of popliteal artery or peroneal nerve injury. Peroneal nerve injury is the most common major neurological problem associated with knee dislocation. The peroneal nerve is evaluated by testing sensation in the first dorsal web space and having the patient extend the big toe or dorsiflex the ankle.

The association between knee dislocations and popliteal artery injury has been known for almost a century. Despite this knowledge, controversy remains concerning the necessity of angiography of the popliteal artery to determine the presence of a vascular injury.

Historically, all patients with knee dislocations have undergone angiography, even those whose vascular examination results are normal. It is currently felt that patients with low-energy knee dislocations whose vascular examination results are normal do not require arteriography but do require serial examination. A study by Miranda et al describe their experience using selective arteriography in 35 patients with knee dislocations during 10 years. In this study, patients with hard signs of vascular injury at the time of evaluation had angiography. “Hard signs” included active hemorrhage, expanding hematoma, absent pulse, distal ischemia, or bruit/thrill over the popliteal artery. None of the 27 patients with negative findings during their physical examinations during their hospitalization ever developed limb ischemia, needed a surgical procedure for a vascular injury, or experienced limb loss. This limited series demonstrates that serial physical examinations have a 94.3% positive predictive value and 100% negative predictive value in diagnosing popliteal artery injury.

Dennis et al reported a study of 38 knee dislocations. Two of these patients had hard vascular signs and popliteal artery occlusion on angiography. The remaining dislocations had no hard signs of vascular injury. Fifty percent of these were treated conservatively with no angiography and no adverse sequelae. The remaining patients had selective angiography, revealing intimal defects or narrowing of the popliteal artery, all of which were treated conservatively with no reported complications.

Some authorities believe that serial physical examinations can obviate the need for arteriography in patients with a knee dislocation that has been reduced and who have normal physical examination results. Doppler pressure measurements may serve as rapid methods for assessing the vascular status. When the ankle/brachial pressure ratio (obtained by dividing the ankle Doppler arterial pressure by the brachial Doppler arterial pressure) is less than 0.8, arteriography should be considered.
1. “He said that he just turned his ankle. He didn’t mention hearing a pop. I didn’t think he would have an Achilles injury.”
All patients with an ankle or foot injury should have their Achilles tendon examined for injury, as this can present in a similar manner as an ankle sprain. This is often a surgically correctable injury that must not be missed.

2. “I know she was in too much pain to let me stress her knee, but it seemed like a simple knee strain. I didn’t think she needed referral to an orthopedist.”
Internal derangements of the knee may be difficult to diagnose in the acute setting because of pain and edema. A conservative approach of referral is usually warranted for any patient for whom an internal derangement is suspected.

3. “I’m pretty sure that he broke his humeral head as a result of the fall that caused his shoulder dislocation. I really don’t think I did it as a result of the reduction.”
Yes, but you can’t prove it. Whenever possible, obtain a radiograph of a patient with a suspected shoulder dislocation before attempting reduction. The emergency clinician should attempt a “blind” reduction only if there is evidence of serious neurovascular compromise and if there will be a significant delay in obtaining a radiograph.

4. “I didn’t think he had a knee dislocation. His knee joint appeared normal on x-ray.”
Many knee dislocations reduce spontaneously before evaluation by a emergency clinician, and all that remains is edema and ligamentous instability. Consider the mechanism of injury (especially high-energy injuries) and the patient’s history with regard to the appearance of the knee just after the injury. Document a thorough neurovascular examination (including ankle/brachial index in the case of significant trauma) and always consider a popliteal artery injury. Assume a dislocation if the knee is grossly unstable on examination.

5. “You manage a Jones fracture the same as any other metatarsal fracture—with a cast shoe. Right?”
Wrong. These injuries have a higher number of complications, such as nonunion, and need to be immobilized properly with a posterior splint, and the patient needs to be referred to an orthopedist in a timely manner.

6. “He said he had knee pain. His knee examination results were normal, so I diagnosed a strain and discharged him.”
Hip disorders can cause referred knee pain and should be considered in any patient with knee pain and normal knee examination results. Even if there is no complaint of hip pain, the hip should be examined, and this should be documented.

7. “The results of her shoulder series of radiographs were normal. The technician forgot to do an axillary view, but I didn’t think it was important.”
Sometimes the only way to diagnose a posterior shoulder dislocation is via an axillary (or scapular-Y) view. This is an important injury that cannot be missed. It is the responsibility of the ordering emergency clinician to be sure that an appropriate series of radiographs is obtained.

8. “He was too sleepy after the conscious sedation I gave him to reduce his elbow dislocation. He didn’t complain of any numbness or weakness in his hand.”
Ulnar nerve entrapment should be considered after reduction of an elbow dislocation. The patient may not volunteer that he or she has ulnar nerve distribution numbness and weakness. This needs to be tested and documented before and after the reduction.

9. “His x-ray results were normal. I didn’t think he broke his ankle. Sure, he couldn’t bear weight on it, but he’s just a kid. They heal quickly, right?”
In children, fractures are more common than sprains. Some Salter-Harris injuries are difficult to detect on initial radiograph. Use caution and assume a fracture to be present; then treat it accordingly.

10. “How could he have ruptured his quadriceps muscle? He was able to walk, and I could move his knee without any problem.”
Patients with rupture of the extensor mechanism of the knee can still can walk and have normal passive range of motion—they just cannot extend their knee against gravity.
The dislocation should be reduced immediately with longitudinal traction after appropriate analgesia and sedation. The reduction is usually accomplished with very little difficulty. The leg should be placed in a long leg posterior splint with 15° to 20° of flexion.

Current recommendations continue to mandate that absent pedal pulses or signs of distal ischemia require immediate angiography and vascular surgery consultation. Those patients with a delay in diagnosis often fail to revascularize within the 6 to 8 recommended hours, resulting in unnecessarily high amputation rates. Greater than 8 hours of ischemic time leads to an 85% amputation rate compared with 85% successful revascularization when ischemia lasts less than 8 hours.85

Perron’s study points out that dislocations that spontaneously reduce have the same risk of arterial injury as those knees still dislocated. Thus, patients with blunt knee trauma without “hard signs” of vascular injury, with an ankle-brachial index greater than 0.9, and with normal pulses require frequent neurovascular checks. Patients who do not meet those criteria need emergent angiograms.

A 2009 case report in the Journal of Emergency Medicine cautions against confusing compartment syndrome with popliteal injury in patients without lower extremity pulses.86 In a patient (thought to be assaulted) complaining only of lower extremity pain, compartment pressures were found to be elevated, radiographs revealed no fractures, the white blood cell count was elevated at 21,000, hemoglobin was 8.8 g/dl, and an anion gap acidosis of 25 mEq/L was found.

Only after an emergent fasciotomy and persistent absence of lower extremity pulses did a computed tomography angiogram reveal the popliteal injury. The patient had a posterior dislocation that spontaneously reduced, leading practitioners down the wrong path. Both conditions can cause severe pain, swelling, exquisite tenderness limiting a physical examination, paresthesias, and pallor. However, the total loss of pulses is a late finding in compartment syndrome, unlike the immediate loss following blunt knee trauma.

**Patella Dislocation**

The common mechanism of injury for a patella dislocation involves a twisting injury when the foot is planted. The patella can also dislocate following a direct blow.36,87 The patella usually dislocates laterally and in many cases will spontaneously relocate. Patients often give a history of the knee “going out of place” and then returning to normal. (Also consider knee dislocation in this scenario.)

If the physical examination reveals only a tender swollen knee and the patella appears to be in place, then the apprehension test may be useful.

It is important to evaluate the knee for ligamentous or meniscal injuries, because 12% of patella dislocations will have a concomitant major injury.72 Severe hemarthrosis is most commonly seen with an osteochondral fracture or ACL injury. Standard radiographs should be evaluated for avulsion fracture, intraarticular fragments, osteochondral fracture, and patella dislocation.4,88,89

To reduce a patella, extend the patient’s leg while applying gentle pressure on the patella in the medial direction. Conscious sedation may be required. Once reduced, place the knee in an immobilizer in full extension with ice application for 20 minutes per hour during the first 24 hours. The knee immobilizer should be worn for 3 to 7 weeks, with progressive weight bearing as tolerated. Refer the patient to an orthopedist.

**Patella Tendon Rupture**

Ruptures of the patella tendon usually result from pivoting, twisting, or a deceleration, such as rebounding in basketball. They are usually associated with other significant ligamentous injuries. On examination, place the knee in 90° of flexion and palpate for a gap in the tendon or a high-riding patella (patella alta). It is important to note that patients with quadriceps or patellar tendon ruptures can still walk. (They have a peculiar forward-leaning gait that allows gravity to extend the knee.) The best way to test the extensor mechanism is to have the patient extend his or her knee against gravity—passive range of motion may be normal. Radiographs may reveal a patella riding high on the femur rather than in its usual location over the knee joint.

Early diagnosis of patellar tendon rupture is important, as undetected injuries can lead to proximal retraction of the patella with resultant quadriceps contraction and adhesions.52 Emergent orthopedics consultation is indicated. (See Figure 10.)

**General Treatment Strategies For Knee Injuries**

After any significant knee injury, protect the knee with a knee immobilizer, placing the knee in 20° to 30° of flexion. The RICE mnemonic (rest, ice, compression, and elevation) is generally recommended. Orthopedic referral is indicated for all patients with suspected ligamentous instability or a fracture.51

**Arthrocentesis**

Arthrocentesis in the setting of a severe injury has limited diagnostic value. Any immediate posttraumatic effusion is assumed to be a hemarthrosis. Although fat globules in the aspirate are characteristic of intraarticular fractures, they can also represent significant soft tissue injury.90 To visualize the globules, place the aspirate in an emesis

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Orthopedic Sports Injuries: Off The Sidelines And Into The Emergency Department
basin for a few minutes, allowing the globules to rise to the surface.\textsuperscript{51}

Arthrocentesis may permit better examination of the injured knee. Decompression of a large effusion and instillation of a local anesthetic affords significant pain relief. This relief is only temporary, however, and the hemarthrosis tends to recur within the first 24 hours because of the loss of the tamponade effect. The usual treatment of rest, ice, compression, and elevation—especially compression—is important postarthrocentesis.\textsuperscript{51}

Intraarticular injection of morphine and bupivacaine has been used for its analgesic effect after traumatic knee injuries and elective knee arthroscopy. Recent studies have shown that both drugs reduce the need for systemic analgesia; morphine is more effective and can provide relief for up to 24 hours.\textsuperscript{91-94} However, these few studies have all been done in postoperative patients without severe injury. The typical dosage is 1 to 5 mg of morphine (1 mg/mL diluted in normal saline to a total volume of 30 mL), although a more concentrated dosage with less volume is a reasonable option.

Achilles Tendon Rupture

Of all spontaneous tendon ruptures, complete Achilles tendon tears are most closely associated with sports activities.\textsuperscript{53} This injury usually occurs with sudden acceleration or jumping, such as in soccer, track and field, basketball, or racquet sports, but it can even occur just by stepping off a curb.\textsuperscript{53} Conditions that predispose to Achilles tendon rupture include rheumatoid arthritis, gout, systemic lupus erythematosus, hyperparathyroidism, chronic renal failure, and corticosteroid or fluoroquinolone use.\textsuperscript{95, 96} The patient usually experiences a sudden pop or snap in the foot or ankle with associated pain. The pain may be minimal and resolve spontaneously.

**Figure 10. Knee Injuries**

A: Rupture of a quadriceps tendon; B: Fracture of the patella; C: Rupture of the patella tendon; D: Avulsion of the tibial tuberosity.


Achilles tendon rupture is missed in up to 25% of patients by the initial examiner, perhaps because patients can still plantar flex (using the toe flexors and other muscles).\textsuperscript{97} Although the defect in the tendon may be palpated, edema and hemorrhage can quickly obscure the gap. This injury is best assessed using the Thompson’s test (also known as the Thompson’s squeeze test). The patient is placed prone on the bed with his or her knees flexed to 90° (feet in the air). The calf muscles are squeezed just distal to their widest girth, and the movement of the foot is observed. The absence of plantar flexion of the foot defines a positive test. This was shown to be accurate in 19 of 19 cases in an autopsy series reported by Thompson and Doherty.\textsuperscript{98} Although this test can have negative results with partial tears, incomplete injuries are thought to be uncommon.

MRI is diagnostic but is usually left to the consultant. Some emergency clinicians obtain plain radiographs to exclude a fracture, as associated ankle or foot fractures are sporadically reported.\textsuperscript{99-102} Treatment involves casting and/or a surgical procedure. It is important to make this diagnosis at the time of initial evaluation, because this can be a debilitating injury if left untreated. If the patient is discharged, splint the foot in plantar flexion and have the patient see the orthopedist within several days.\textsuperscript{71}

Gastrocnemius Strain

Gastrocnemius strain, also known as “tennis leg,” is a strain involving the musculotendinous junction of the medial head of the gastrocnemius and the Achilles tendon. The injury occurs following a vigorous propulsive movement such as a jump or sudden start. The patient reports a pop in the medial upper calf. There is instant pain, and spasm of the calf muscles results in plantar flexion. On examination, there is exquisite point tenderness at the medial junction of the middle and proximal thirds of the calf. Swelling and ecchymosis usually occur distally. Assess the Achilles tendon function using the Thompson’s test. Treatment involves a posterior splint with the foot at 90°. Dorsiflexion must be started within 24 hours postinjury to regain ankle motion.\textsuperscript{31}

**ED Evaluation: Ankle Injuries**


Ankle sprains are the most common of all ankle injuries (85% of all severe ankle injuries are sprains\textsuperscript{102}) and are especially likely to be sustained in sports and recreational activities.\textsuperscript{52} At present, functional treatment is the rule, and less impor-
stance is attributed to differentiating between single and multiple ligament injuries. The ankle is often injured during football when a player attempts to change direction quickly on an outside leg that is planted during pivoting. A player’s ankle may also be injured by being stepped on.

Some controversy exists regarding the optimal treatment of ankle sprains. A recent systematic review of 12 studies of high methodological quality evaluated functional treatment versus immobilization. The data favor the functional approach (early mobilization as tolerated) for the following outcomes: return to work and sports, short-term resolution of swelling, and intermediate subjective stability. Immobilized patients were more likely to have impaired range of motion. Patients in the functional management group were more likely to be satisfied with their care in the short and intermediate term and tended to report less pain. No differences were noted between subjective stability and rates of recurrent ankle pain.

Current treatment advocates early mobilization for lateral ankle sprains. Unfortunately, pain may be a limiting factor in enabling patients to meet this therapeutic goal. A 2006 double blind, randomized study in the *Annals of Emergency Medicine* compared extended release acetaminophen with ibuprofen for grade I or II lateral ankle sprains. Although acetaminophen is an efficacious analgesic, studies have never been conducted to prove efficacy in ankle sprains. The study’s noninferior design revealed that acetaminophen was no worse than ibuprofen and spared some of the gastrointestinal symptoms, such as nausea and dyspepsia, commonly experienced after ibuprofen ingestion.

It was thought that ibuprofen was needed to treat these injuries, because it has anti-inflammatory effects that acetaminophen does not possess. However, we can conclude from this study that the swelling resulting from mild to moderate injuries such as grades I and II lateral ankle sprains will spontaneously resolve, and treatment to decrease the inflammation is not necessary.

**ED Evaluation: Foot Injuries**

**Anatomy, History, And Physical Examination**

The foot is divided into 3 anatomic regions: the hindfoot, which includes the talus and calcaneus; the midfoot, which includes the navicular, cuboid, and cuneiforms; and the forefoot, which includes the metatarsals, phalanges, and sesamoids. (See Figure 11.)

Determine whether the injury was a result of direct trauma or a torsional force. Ask the patient about the location of the pain, ability to ambulate, and previous injuries and operations. A directed physical examination should include inspection for edema and ecchymosis, palpation to localize pain, a neurovascular examination, and range-of-motion examination. Tenderness over the navicular and the base of the fifth metatarsal should be targeted for special attention, as these bones are statistically the most likely to be injured.

A standard radiographic series of the foot includes AP, lateral, and 45° internal oblique views. Overlapping bones, accessory centers of ossification, and sesamoids can complicate interpretation.

**Types Of Injuries**

A variety of athletic activities can result in foot injuries. An injury identified with increasing frequency in snowboarders (but difficult to detect on plain radiographs) is fracture of the lateral process of the talus. The midfoot is also frequently injured, especially the tarsometatarsal joint, also known as Lisfranc’s joint. A Lisfranc injury is any injury to this joint or bones contiguous with the joint. These injuries can occur in a sport that involves fixation of the forefoot, such as equestrian activity and windsurfing. This injury also occurs in football when the player sustains a blow to the back of the heel, or in baseball while sliding into a base.

On examination, there is tenderness along the dorsal aspect of the midfoot and variable amounts of swelling. Joint laxity may be present. Spontaneous reduction of this fracture often occurs, resulting in subtle radiographic changes. On the lateral view, look for anatomic alignment of the dorsal margin of

**Figure 11. Foot Anatomy**

![Figure 11. Foot Anatomy](image)
the first metatarsal with the lateral cuneiform. AP views should reveal exact alignment of the medial edge of the second metatarsal and intermediate cuneiform. Fractures of the bases of the metatarsals or cuboid fracture suggest severe ligamentous injury as well. Initial management involves splinting and outpatient orthopedic referral to assess the need for surgical repair.52

Although Lisfranc injuries are rare (occurring in 1 per 55,000 persons per year), misdiagnosis occurs in approximately 20% of all cases.106 Prolonged disability and chronic pain can result from misdiagnosis or delay of appropriate treatment. An article in the Journal of Trauma reports that the injury is frequently missed in the ED although no data are presented to support that.108 Vuori does comment, though, that Lisfranc joint injuries can be caused by low-energy trauma, such as a stumble or fall, 33% of the time.

High-energy forces cause the same percentage of injuries, and the article advocates keeping this injury in mind for a simple twisting injury to the forefoot with persistent pain. No association was discovered between the severity of the mechanism and the degree of injury to the Lisfranc joint, meaning that a simple fall has caused complete dislocation of the joint. The best indicator for severity of injury was the total number of fractured metatarsals and whether the midtarsal region was involved.

An article in Annals of Emergency Medicine concerned about the common misdiagnosis of Lisfranc fractures/dislocations points out that gross subluxation or lateral deviation of the forefoot is often not present.109 The usual symptoms are midfoot pain, swelling, and difficulty bearing weight. While holding the hindfoot, the practitioner should gently supinate and pronate the forefoot. This maneuver will invoke pain in patients with a Lisfranc injury. Edema persisting after 10 days should initiate a workup for Lisfranc injuries. The distal skin, dorsalis pedis pulse, and capillary refill should be gauged because cases of dorsalis pedis compression or laceration have been reported following Lisfranc trauma.110

The Jones fracture is a transverse fracture at the proximal metaphyseal-diaphyseal junction of the fifth metatarsal. (See Figure 13.) This is commonly confused with a fracture of the tuberosity of the fifth metatarsal base. These are different injuries and require diverse management. The Jones fracture has a significant risk of delayed union or nonunion. The mechanism of injury is a load applied to the lateral forefoot without inversion, such as in sports involving running and jumping.4 Most metatarsal fractures can be treated with a cast shoe, but the Jones fracture

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**Figure 12. Lisfranc Fracture-Dislocation With An Avulsion Fracture (Arrow) Of The Lateral Aspect Of The First Cuneiform**


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**Figure 13. Jones Fracture**

This patient complained of injuring her ankle, and the ankle was examined radiographically. The frontal (a) and internally rotated oblique (b) projections demonstrate the Jones fracture (arrow) of the base of the fifth metatarsal.

requires splinting and possible surgical management. A severe fracture can be treated by immobilization in a posterior splint with non-weight bearing and orthopedic referral.4

Turf toe refers to a sprain of the first metatarsophalangeal joint. This term was coined in 1976, when the injury was attributed to hard, artificial turf playing surfaces.52 In most cases, the injury occurs as a result of hyperextension (dorsiflexion) of the joint. Examination reveals pain and swelling of the great toe with painful range of motion. Radiographs may show a capsular avulsion fracture involving the first metatarsal head or the base of the proximal phalanx. The mainstay of treatment for this injury is rest, which is difficult to enforce in some athletes. Compression dressing, elevation, and ice are also useful, as well as NSAIDs. Taping the toe to resist dorsiflexion also helps to relieve pain and control swelling.52 Cortisone or anesthetic injections are not indicated and can prolong recovery.111

Special Considerations For Injuries In Young Athletes

Schmidt et al compared the frequency of sports injuries in children with their physical location.112 They found that almost 44% of all injuries involve the upper extremities, 16% involve the head, and 34.5% involve the lower extremities. The peak prevalence for injuries is age 12. In general, sprains, contusions, and lacerations account for most injuries. In the lower extremities, the knee joint is the most commonly injured area.61,87

Epiphyseal Injuries

The ligaments and articular capsule are firmer than bone and the epiphyseal plate in children.113 As a result, trauma to this region of the maturing skeleton usually injures the cartilaginous epiphyseal plate.4 These injuries result from shearing and avulsion forces as well as compression. The cartilaginous cells of the epiphysis may be damaged, resulting in premature closure of the epiphyseal plate and disturbance in bone growth. (See Figure 14.)

Upper Extremity Injuries

The clavicle is the most commonly fractured bone in children.97 Most of these fractures are greenstick injuries of the midshaft clavicle. Associated neurovascular injury is rare. However, as in adults, posterior displacement of the clavicle from the sternoclavicular joint can cause compression of the trachea or mediastinal vessels. Treatment is sling of the shoulder and analgesia.

GH dislocations are unusual before physeal closure. As in adults, most dislocations are anterior. Diagnosis and treatment are the same. Orthopedic referral is essential, as many of these patients can develop chronic instability.

More than 50% of elbow fractures are supracondylar and occur as a result of a fall on an outstretched arm with hyperextension at the elbow. Direct vascular injury is uncommon, but the pulse may be diminished secondary to arterial spasm. Neurologic deficits are usually transient but can be due to direct nerve injury. Emergent orthopedic consultation is usually

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**Figure 14. Salter-Harris Classification Of Epiphyseal-Metaphyseal Fractures**

- Type I: The epiphyseal line (physis) is widened secondary to some degree of epiphyseal separation. The epiphysis may or may not be displaced.
- Type II: There is some large or small metaphyseal fracture fragment in association with widening of the epiphyseal line. The epiphysis and fracture fragment may or may not be visibly displaced.
- Type III: In this type, the fracture occurs through the epiphysis and the fracture may or may not be displaced. When displacement occurs, often only part of the fractured epiphysis is displaced.
- Type IV: A fracture exists through the epiphysis and the metaphysis; displacement of the fragments may or may not be present.
- Type V: An impaction fracture with injury of the epiphyseal plate only is present. No roentgenographic findings other than swelling around the involved epiphyseal-metaphyseal junction usually are present.

Reproduced with permission from: Swischuk LE. Emergency Imaging of the Acutely Ill or Injured Child. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2000. Figure 4.8.
**General Treatment Principles For Musculoskeletal Injuries**

The RICE regimen (rest, ice, compression, and elevation) is generally recommended for patients with orthopedic sports injuries. Analgesia—usually NSAIDs—may also be appropriate, depending on the circumstances.

A systematic literature review suggests that melted ice water applied through a wet towel for 10-minute intervals is the most effective technique for lowering the temperature of the underlying structures, but there is no proof that this affects clinical outcome. The target temperature reduction is 10°C (50°F) to 15°C (59°F). Using repeated rather than continuous ice applications helps sustain reduced muscle temperatures without compromising the skin. There are no large, randomized studies to help the emergency clinician decide how often and how long to use ice.

Heat is generally not recommended for severe injury, but it has theoretical benefit. No large, controlled trials of heat therapy for severe injury were found in 1 MEDLINE search.

**Hip/Pelvis Injuries**

The presence of unfused epiphyses predisposes the pediatric hip and pelvis to traction injuries. Large fragments of bone can be avulsed with sudden and unexpected loads. The anterior superior iliac spine can be avulsed during football when the kicking foot is suddenly blocked or tackled. The psoas muscle can also avulse off the lesser trochanter. The whole apophyseal plate of the ischium can separate via a pull of the hamstrings. This can be caused by overstretching the leading leg while running. Treatment for any of these injuries is conservative, and a surgical procedure is rarely needed.

**Knee Injuries**

An avulsion injury may mimic a tear of the ACL. The ACL remains intact, but a large piece of the proximal tibia is avulsed secondary to flexion, twisting, or hyperextension.

In pediatric knee injuries, radiograph results may be normal but be suggestive of a significant injury if the knee is unstable. An unwary emergency clinician may mistake a tibial tubercle for an avulsion fracture. Meniscal problems in this age group are uncommon.

Physeal fractures in the region of the knee may be associated with ligamentous injuries. Immobilization and prompt orthopedic referral are mandatory.

**Ankle Injuries**

The twisting injuries that cause a fracture in adults produce a different pattern of injury in the immature skeleton. Inversion trauma to the ankle of a skeletally immature patient frequently causes separation of the distal fibularphysis and spares the lateral ligaments. Physeal fractures are commonly misdiagnosed as ankle sprains, because spontaneous reduction usually occurs and radiographs reveal no bony abnormality. In general, ankle fractures in children are minimally displaced. However, when they involve the articular surface, they may require a surgical procedure.

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**Cost-Effective Strategies For Orthopedic Sports Injuries**

1. Do not x-ray every knee, ankle, or foot. The Ottawa knee, ankle, and foot criteria are sensitive and specific. Adherence to these criteria whenever possible will decrease the number of knee radiographs ordered.
2. Do not order an MRI from the ED for knee injuries. MRI is an outpatient study that should be ordered by the orthopedic consultant who will be treating the patient.
3. Avoid the use of ketorolac for severe musculoskeletal injuries. Ibuprofen has been shown to be just as effective for severe pain and is significantly less expensive. If ibuprofen is ineffective in relieving the patient’s pain, opioid narcotic analgesics should be prescribed.
4. Learn to use intraarticular lidocaine to reduce shoulder dislocations. It is less expensive and faster than intravenous sedation and is just as efficacious.
Conclusion

Although sports injuries are common, they do present several distinct challenges to the emergency clinician. Above all, the emergency clinician must accurately determine whether the injury is stable or unstable. This key determination drives further management, including the type of follow-up and referral that are necessary. Knowing which types of injuries can masquerade as seemingly trivial injuries will serve the patient and emergency clinician alike.

Radiography associated with orthopedic sports injuries is costly, and the radiographs are often negative. Important aspects of the history and physical examination, including some physical examination maneuvers, can help obviate the need for radiography under some circumstances and increase the index of suspicion for serious injury in others. Clinical decision rules such as the Ottawa ankle rule, Ottawa knee rules, and Pittsburgh knee rules are medically appropriate and cost-effective.

References

Evidence-based medicine requires a critical appraisal of the literature based on study methodology and number of participants. Not all references are equally robust. The findings of a large, prospective, randomized, controlled trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, is included in bold type following the reference, where available. In addition, the most informative references cited in the chapter, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.


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21. Reduction of glenohumeral dislocations:
   a. Requires orthopedic consultation in the vast majority of cases
   b. Generally requires conscious sedation
   c. Can often be performed with intraarticular lidocaine, which shortens ED stays and reduces costs significantly, instead of conscious sedation
   d. Does not require orthopedic follow-up in children

22. All of the following are true about “jersey finger” except:
   a. It is a rupture of the extensor tendon that attaches to the dorsal side of the distal phalanx of the finger.
   b. It is a tear of the flexor digitorum profundus.
   c. The physical examination is diagnostic of this injury.
   d. The finger should be splinted with the finger and wrist flexed and urgently referred to a hand specialist for operative management.

23. Rotator cuff tears:
   a. Are usually acute
   b. Can be identified by supraspinatus atrophy, weakness with elevation or external rotation of the shoulder, or the impingement sign
   c. Most clavicle fractures occur in the middle third of the clavicle.
   d. Randomized, controlled clinical trials show equivalent outcomes with figure-of-eight clavicle straps and simple slings for middle-third clavicle fractures.

24. The unilaterality, brevity, and pain-free range of motion in the athlete can assist in discriminating between a “stinger” and a cervical cord injury.
   a. True
   b. False

25. The sport most likely to result in an elbow dislocation is:
   a. Gymnastics
   b. Tennis
   c. Football
   d. Weight-lifting

26. A “hip pointer”:
   a. Is a contusion of the iliac crest
   b. May result in severe disability because the iliac crest serves as an anchor for abdominal and hip musculature
   c. Usually results from a direct blow to the hip
   d. Is treated with ice, analgesics, and possibly a six-to-eight-day steroid burst to reduce the duration of disability
   e. All of the above

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**CME Questions**

17. Patients with low-risk shoulder injuries include:
   a. Those with no fall and no swelling
   b. Those with a fall but no swelling or pain at rest
   c. Those with a fall and pain at rest but no swelling and normal range of motion
   d. Any of the above
   e. None of the above

18. Two-part proximal humeral fracture-dislocations should be reduced in the ED.
   a. True
   b. False

19. All of the following are true about clavicle fractures except:
   a. They usually result from a direct blow to the clavicle or a fall on an outstretched arm.
   b. Pneumothorax is a common complication of clavicle fracture.
   c. Most clavicle fractures occur in the middle third of the clavicle.
   d. Randomized, controlled clinical trials show equivalent outcomes with figure-of-eight clavicle straps and simple slings for middle-third clavicle fractures.

20. The appropriate disposition of patients with glenoid fractures is:
   a. Immobilization and orthopedic referral within three days
   b. Urgent orthopedic consultation
   c. Urgent surgical consultation
   d. Discharge home with the RICE regimen and NSAIDs
27. ACL tears and meniscal injuries are more likely to result from sports injuries than other mechanisms.
   a. True
   b. False

28. The Lachman test evaluates the ACL and is the single best clinical test for determining the integrity of the ACL.
   a. True
   b. False

29. All of the following are part of the Ottawa knee rules except:
   a. The patient is 55 years or older
   b. There is tenderness at the head of the fibula or isolated tenderness of the patella
   c. The patient is unable to flex the knee to 90°
   d. The patient is unable to take four steps both at the time of injury and at time of evaluation
   e. The injury is more than seven days old

30. Meniscal injuries:
   a. Classically involve joint line pain, swelling, and locking
   b. Can be ruled out by a negative McMurray test
   c. Require urgent orthopedic consultation
   d. Can be ruled out if the knee has been fractured or displaced

31. In orthopedic foot injuries, the navicular and the base of the fifth metatarsal are statistically the least likely to be injured.
   a. True
   b. False

32. All of the following are true about sports injuries in children except:
   a. The ligaments and articular capsule are firmer than bone and the epiphyseal plate.
   b. 44% of all the injuries involve the upper extremities, 16% involve the head, and 34.5% involve the lower extremities.
   c. In contrast to adults, trauma in children is more likely to injure the cartilaginous epiphyseal plate than ligaments.
   d. Epiphyseal injuries are unlikely to disturb future bone growth.
Blunt Abdominal Trauma: Priorities, Procedures, And Pragmatic Thinking

Four a.m. — things are just starting to calm down in the ED. Suddenly, a worried mom arrives with her 14-year-old son. It seems he was doing tricks on his scooter, and during a flip he rammed the handlebar into his upper abdomen. He wouldn’t eat dinner and started vomiting around midnight. His belly is fairly benign except for a bruise just below his xiphoid. Oh, well — it’s probably just another case of gastroenteritis.

“T he belly is benign” takes its place among other cringe-causing statements in the emergency medicine lexicon (such as “Remember that older gentleman you sent home last night?”). What should accompany such abominable proclamations is the trailing caveat “but he’s intoxicated...is head injured...has a fractured femur...has a seat belt mark...has a cervical cord injury...” and so forth. Worse, though, is the failure even to suspect that abdominal trauma is a possibility in the well-appearing patient.

The diagnostic approach to blunt abdominal injury has shifted in the past 4 decades. Before the advent of diagnostic peritoneal lavage (DPL) in 1964, clinical examination was the primary modality. However, its limited accuracy led to a considerable number of unneeded laparotomies and, more disturbingly, failure to operate in a timely manner on those in need. DPL was the mainstay from its inception until the 1980s, when computed tomography (CT) became routinely available. Over the past decade, ultrasonography (US) has found its way into the mix, mostly as a noninvasive replacement for DPL to search for intraperitoneal blood. Today, these 4 tools are used in various combinations for differing clinical scenarios in emergency departments (EDs) across the country.

Current practice emphasizes cost-effective and efficient approaches. This may include a strategy of simply observing patients with reliable examinations without any positive findings unless and until they develop indications for specific diagnostic studies.1 Decision trees vary widely among institutions according to the reliability and availability of the various technologies as well as the experience and preference of emergency clinicians, trauma surgeons, and radiologists at the respective sites.2,3 What is clear is that pragmatic thinking, attention to detail, and effective clinical algorithms will help the emergency clinician detect occult injury and treat the traumatized patient. This chapter outlines just such an approach.

Epidemiology

Blunt abdominal trauma is responsible for 10% of all trauma deaths. Motor vehicle crashes and automobile/pedestrian injuries are responsible for one-half to three-quarters of blunt abdominal injury, and assaults and falls make up the majority of the remainder.4 Importantly, the bulk of patients with abdominal trauma present within the context of multisystem trauma. These are often patients involved in a high-speed crash who present with simultaneous closed head injury, hemopneumothorax, multiple extremity fractures, and numerous lacerations.

Nonaccidental trauma in children can be an especially elusive diagnosis. A history of child abuse is often difficult to secure based on the child’s fear coupled with the parents’ misdirection.5 These small patients may also suffer less common injuries, such as duodenal hematoma or pancreatic injury. Likewise, domestic violence may result in occult abdominal trauma, especially in females and, more particularly, in pregnant women. Iatrogenic injury can be induced by bag-mask ventilations, inadvertent esophageal intubation, external cardiac compressions, and the Heimlich maneuver.6,7

CME Objectives

Upon completing this article, you should be able to:
1. Name typical mechanisms of injury for solid and hollow visceral trauma.
2. Explain the appropriate diagnostic approach based upon the clinical scenario.
3. Describe which clinical and laboratory features are useful for patients with blunt abdominal trauma.
4. Adapt the management approach in the context of special patient and clinical circumstances.

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Pathophysiology

Three basic mechanisms cause intraabdominal injury. First, an external force applied to the anterior wall and the posterior thoracic cage or vertebral column can crush those organs caught between. This is more likely to occur to solid organs (particularly the liver and spleen) and in those with lax abdominal walls (typical of the elderly as well as alcoholic patients). Second, abrupt and powerful external forces can suddenly increase intraabdominal pressure and burst a hollow viscus. This is exemplified by lap belt injuries. Third, extreme acceleration-deceleration can shear the solid viscera as well as vascular pedicles.

The spleen is the most frequently damaged intraperitoneal organ, followed by the liver. The intestine is the most likely hollow viscus to sustain injury.

Differential Diagnosis

Sure, it is possible that a patient presenting with abdominal pain and tenderness following a major car crash is simply doubled over from preexistent pelvic inflammatory disease, appendicitis, lead poisoning, or even acute intermittent porphyria. Guess again. The traditional differential formula does not adapt well to abdominal trauma. With that in mind, though, there are 3 considerations that warrant mention:

1. Single-versus Multisystem Trauma: Major forces inflicted by vehicles at high speeds tend to produce multisystem trauma. It is ill-considered to suppose that a patient thrown 50 feet from the train that hit him has an isolated leg fracture. Suspect the abdomen in this scenario.

2. Single-versus Multiple-Organ Injury: There has been considerable emphasis in the past 15 years on avoiding laparotomy when there is known or strongly suspected isolated solid organ (ie, spleen, liver) injury. This is especially true in children. Unfortunately, coincident hollow viscus rupture is not rare in these circumstances and can be very difficult to identify by clinical examination or certain diagnostic studies, such as CT.

3. Trauma versus Medical: Medical problems can precipitate or coexist with trauma, especially in the elderly. Metabolic, anaphylactic, cardiac, or neurologic emergencies may cause the fall or motor vehicle crash. What appears to be closed head injury may simply be hypoglycemia.

Patients with enlarged or abnormal intraperitoneal organs (eg, the enlarged spleen of infectious mononucleosis) or coagulation disorders can have profound injuries subsequent to what seems to be the most trivial trauma.

Prehospital Care

Paramedics are the emergency clinicians’ eyes and ears at the scene. They can transmit invaluable information on the mechanism of injury and can determine seat belt use, starred windshields, bent steering wheels, and vehicular intrusion. They provide clues to severity of injury by reporting prehospital vital signs and neurologic status.

From a management perspective, the “scoop and run” strategy prevails. Procedures such as intravenous insertion and intubation can usually be carried out in the rig. Wherever possible, paramedics should notify receiving hospitals regarding high-acuity patients to allow preparation. The appropriate receiving hospital is determined by a combination of triage-scoring systems and paramedic judgment.

Nearly all studies show that the pneumatic antishock garment (PASG), a device prematurely popularized in the 1970s, is ineffective in most patients who suffer blunt trauma. However, in 1 retrospective, nonrandomized study, severely hypotensive trauma patients (blood pressure ≤ 50) seemed to benefit from the application of the PASG. However, it or an alternative pelvic-stabilizing device is indicated to mitigate the massive retroperitoneal hemorrhage that can occur in patients with pelvic fracture. Although it appears reasonable that the PASG would assist hemorrhage control in unstable pelvic fractures, no large, randomized, controlled trials have evaluated this.

Finally, recent studies have elaborated potential risks of aggressive crystalloid resuscitation, especially in patients with penetrating torso trauma. This issue remains unresolved at this time, specifically for the patient with blunt trauma. It is reasonable, then, to place lines in the field but to avoid overzealous fluid administration, particularly in those patients injured shortly before transport who have brief transport times. Although the definition of “overzealous” remains a moving target, high-volume infusions are not indicated in those with relatively stable vital signs.

ED Evaluation

I had...come to an entirely erroneous conclusion which shows, my dear Watson, how dangerous it always is to reason from insufficient data.


History

Although not always available, the patient’s history can be extremely valuable. The patient interview may be compromised or impossible due to severe head injury, alcohol or drug intoxication, or the unavailability of key and credible witnesses. Remote history of trauma may be forgotten or considered trivial.
The prehospital events can provide key insight and should include assessment of vital signs, physical assessment, and response to therapy. Consider asking the paramedics, “What was the highest pulse and lowest blood pressure?” Outside records, including x-rays, must be reviewed carefully.

Ask the scene personnel about the extent of damage to the vehicle, amount of passenger compartment intrusion, the condition of the steering wheel and windshield, whether seat belts were used, whether front or side airbags were deployed, and the speed and size of the striking vehicle.

Certain mechanisms portend particular injury patterns. Compressive forces, especially to the rib cage, are associated with liver and spleen fractures. Sudden high-energy forces over a small impact zone are known as “spearing” mechanisms (eg, nose of a football, bike handlebars, and lap belt-only restraint). These frequently result in hollow viscus injury. The organ “speared” can be predicted somewhat based on whether the trauma was centered in the epigastrium (duodenal hematoma or rupture, pancreatic contusion), mid-abdomen (jejunum, ileum), or lower abdomen (ilium, bladder). Finally, high-speed deceleration (eg, a fall from 4 stories or 80 miles per hour into a tree) can shear solid viscera from their vascular pedicles, most notably the kidney.

The condition of the patient at the scene may suggest that a medical concern precipitated the crash or fall. These underlying conditions may contribute to or be wholly responsible for the patient’s status. Seizures, arrhythmias, and hypoglycemia are notable culprits.

Ask about loss of consciousness (LOC) in patients who have experienced blunt trauma. In 1 study, transient LOC in the field was significantly associated not only with head injuries but with extracranial injuries as well. In this series, nearly 20% of patients suffering LOC required a surgical procedure for life-threatening injuries; many needed laparotomies.

The patient with abdominal trauma may have a variety of complaints. There are 2 main presentations. First is volume loss, which, depending on the rate and severity of bleeding, can produce thirst, orthostatic dizziness, light-headedness, confusion, or obtundation. Second, irritation of the peritoneum incites pain and will result directly from hematoma (eg, bleeding from the liver, spleen, or great vessels), infectious (eg, leaking bowel or colon), or enzymatic (eg, pancreas, bowel, gallbladder) irritation. Pain may be present at the outset or lag by hours to days, particularly in the case of hollow viscus or pancreatic injury. Remember that the sensation of pain may be diminished or rendered absent by the presence of competing pain at another body site, altered sensorium, possible intoxication, or spinal cord injury.

Abdominal pain may be diffuse, as when it follows gross hemoperitoneum and septic peritonitis. Local pain can also occur; for instance, splenic injury can produce pain in the left upper quadrant or referred pain in either shoulder tip or the neck. This referred pain is probably due to intraperitoneal irritation of the diaphragm and can sometimes be elicited by placing the patient in the Trendelenburg position (Kehr’s sign). Shortness of breath may occur with diaphragmatic irritation or the herniation of intraabdominal structures into the chest through a diaphragmatic tear. Nausea and vomiting may accompany hypovolemia or peritoneal irritation. Persistent vomiting may be secondary to obstruction and is frequent with duodenal hematoma.

Past Medical History
An understanding of the patient’s comorbid medical conditions such as cardiovascular disease and coagulation disorders or coagulopathic medications (eg, warfarin) can be critical to the management schema, particularly fluid and blood component therapy. Patients on warfarin may develop life-threatening hemorrhage after relatively minor trauma.

Physical Findings
Examine everything; then do it again...and again. The emergency clinician who fails to perform complete primary, secondary, and tertiary surveys will miss clues to shock and serious injury. This admonition certainly applies to the peritoneal cavity. Although the abdomen should never be ignored, it cannot be the sole focus of the emergency clinician.

It may not be easy to perform a careful abdominal examination in the midst of a critical resuscitation — both the patient and the emergency clinician may be distracted from the abdomen. However, abdominal tenderness, peritoneal irritation, gastrointestinal hemorrhage, and hypovolemia not attributable to extraabdominal causes should always suggest intraperitoneal injury. That is the good news. The bad news is that even in the alert and conscious patient, reliance on the abdominal examination can lead to false-positive and false-negative errors. In some patients, the examination may be unremarkable despite intraperitoneal injury, whereas in others it suggests injury when none exists. This situation is made worse by compromising factors-altered sensorium, distracting injury, and the like. Overall, the accuracy of a single physical examination in blunt abdominal trauma is 55% to 65%.

Vital Signs
Blood pressure and pulse should be considered in context. Frank hypotension, tachycardia, or both strongly suggest hemorrhage. However, these findings are not specific for abdominal injury. In addition, premorbid circumstances such as hypertension and the presence of various drugs and medications can alter or mask the response to blood loss.
elderly patient with preexisting hypertension who is taking a beta-blocker can be in profound shock despite a “perfect” blood pressure of 120/80 mm Hg and a pulse of 80.

Even healthy adults may not develop tachycardia despite profound shock. In a study of more than 10,000 major trauma patients, relative bradycardia (defined as a systolic pressure < 90 mm Hg and a pulse rate < 90 beats per minute) occurred in nearly 30% of all hypotensive patients.26

Abdominal Examination
Inspection of the abdomen may reveal distension or ecchymoses. In the case of distension, likely culprits include pneumoperitoneum, gastric dilatation, or ileus. Distension produced by hemoperitoneum alone is extraordinarily ominous and is an extremely late finding. Because 2 liters of free blood in the abdominal cavity will distend the belly almost imperceptibly,27 never wait for this sign to prompt laparotomy. Inspection of the bare trunk may also reveal telltale ecchymoses. Bruising of the flanks (Grey Turner’s sign) or umbilicus (Cullen’s sign)28 represents hemorrhage in the retroperitoneal or peritoneal spaces, respectively. However, these signs are typically delayed by 6 hours to several days.

More valuable is the presence of a lap belt sign. This finding suggests worrisome intraabdominal injury—notably, perforation of the small bowel. As many as one-third of patients with a lap belt sign will have injury to the bowel or mesentery.29 In 1 prospective study, 36% of patients with a seat belt sign required operative intervention.30

Auscultation of the injured abdomen provides little information. Many experienced practitioners believe that the presence of bowel sounds does not rule out ileus or serious injury, and their absence in no way proves that injury exists. However, this premise has not been subjected to in-depth study.

Perhaps the most valuable physical finding in abdominal trauma comes from palpation. Local or generalized tenderness is found in approximately 90% of alert patients with intraabdominal visceral injury.25,31 However, not all abdominal tenderness represents intraabdominal injury. The presence of thoracoabdominal wall trauma (eg, lower chest rib fractures) can make the patient wince in reaction to abdominal palpation that too closely approaches the injured chest. Likewise, severe contusions of the abdominal wall can cause tenderness and guarding. Carnett’s sign is tenderness of the abdominal wall elicited by palpating the abdomen during contraction of the rectus muscles (as when the supine patient lifts his or her head or legs off the gurney).32,33 If the abdomen is more tender with the rectus muscle tense and less tender with the muscles relaxed, this implies muscle as opposed to visceral injury.

However, no prospective studies have validated this finding in the trauma patient.

Forty percent of patients with hemoperitoneum have a benign belly without any peritoneal signs.34 Although some of these patients have head trauma or are intoxicated, the point remains that a physical examination provides limited information. Practitioners need to be meticulous about looking for the caveats to the physical examination mentioned above. Injury to the spleen and the resulting hemorrhage is the number one cause of hypotension after blunt abdominal trauma.35

Extraabdominal Examination
In addition to auscultation and inspection of the chest, palpate the lower chest for rib fractures. As many as 20% of patients with left lower rib fractures have pleural injury, whereas slightly fewer with right lower rib fractures suffer liver damage.36 Assess the pelvis for tenderness and stability.

The rectal examination is rarely of value in severe blunt trauma. It may be valuable in the male with pelvic fracture who is at risk for urethral injury but who has no blood at the meatus. In such a patient, the discovery of a high-riding prostate will prompt the need for urologic studies. In addition, a sacral fracture resulting in sensory loss in the posteromedial thigh and buttocks (S2-S4) demands assessment of rectal tone. Finally, certain intrahepatic hematomas can “liquefy” and empty through the hepatobiliary tree into the duodenum and ultimately the colon. However, this takes place 2 to 3 weeks or more after the original trauma—a long time to wait with a hemoccult card in hand.

Pay special attention to palpating the lumbar spine in the patient with abdominal wall ecchymosis. Patients with a lap belt sign may have sustained a coincident burst fracture of the upper lumbar vertebrae (Chance fracture).37 The combination of a lap belt sign and lumbar fracture places the patient at very high risk for hollow viscus injury.38,39

Serial Examinations
Repeated examinations by the same examiner are helpful in alert patients and are especially so in patients with an altered sensorium. Appropriate documentation should accompany these examinations.

Diagnostic Studies
Patients in whom physical examination results are reliable and normal often require nothing but serial examinations. In those with clinical evidence of hemodynamic compromise or clear thoracoabdominal injury, immediate testing is needed, including baseline hematocrit, type and hold/cross, and 1 or more of the big 3: DPL, US, or CT. Likewise, patients with blunt multisystem trauma who cannot be adequately observed in the ED should undergo
sufficient diagnostic evaluation to preclude life-threatening intraabdominal injury before a nonabdominal operation (eg, craniotomy, thoracotomy) or diagnostic study (eg, aortogram). Occasionally, the patient with overwhelming clinical indications for laparotomy may be taken to the operating room (OR) with no additional testing. Such patients may include those with isolated abdominal trauma who have a rigid abdomen, refractory hypotension, and no other possible sources of blood loss.

**Laboratory Studies**

*I have become deeply impressed with the general reliance on laboratory methods shown by practitioners recently out of college, and at the same time with their inability accurately to observe or appreciate the significance and value of symptoms as compared with the finding of the microscope or test tube.*

—Robert Hall Babcock, The Lancet Clinic, 1911

Overall, hematologic and chemical tests provide little assistance to the patient with severe blunt trauma. Instead of routine testing, laboratory investigation is best tailored to the clinical circumstances. In 1 prospective study, researchers divided trauma patients into 2 categories: Trauma Blue—severe injury likely (Glasgow Coma Score [GCS] < 13; systolic blood pressure < 100 mm Hg at any time; significant head, chest, abdominal, or proximal long bone injury; or clinical suspicion of need for operative or intensive care unit management) and Trauma Yellow—severe injury unlikely. The tests ordered for Trauma Blue included an arterial blood gas (including pH, PO₂, PCO₂, HCO₃⁻ base deficit, hemoglobin, sodium, potassium, and ionized calcium), blood alcohol, type and screen or crossmatch, and urine dipstick.

Tests for the Trauma Yellow group were limited to a venous blood gas and blood alcohol. In this study, no patient suffered delay in care because of lack of laboratory testing—and cost savings were $29.82 per patient (or $20,000 a year) at this institution. However, this study did not examine the equally appealing hypothesis that no tests may be required in the patient in whom the emergency clinician does not suspect serious injury. Other studies have shown similar results.

**Hematology**

The hematocrit is most useful as a baseline study or when significantly low when the patient arrives (< 30%). Remember that the hematocrit reflects some combination of a pretrauma value, the lag from hemorrhage, and dilutional effects of exogenous fluid administration and endogenous plasma refill. In patients with a 10% to 20% blood loss, the endogenous plasma refill proceeds at a modest rate of 40 mL/h for the first 10 hours, continuing for 30 to 40 hours. However, in a very remarkable study of volunteer patients with blood loss of at least 40% of total blood volume (how much were these volunteers paid?), this rate could be as high as 1500 mL in the first 90 minutes following injury.

Although a low hemoglobin level observed after injury usually indicates serious hemorrhage (and occasionally underlying anemia), most trauma patients have an initial hemoglobin in the normal range, even despite significant blood loss. Serial levels are often more informative. Recall, however, that 1 liter of intravenous fluids alone (without blood loss) may decrease the hemoglobin level by a point or more. Part of medical mythology holds that an elevated white count on the complete blood count suggests splenic injury. However, leukocytosis with a count of 12,000 to 20,000 and moderate left shift is a common occurrence within several hours of any major injury. It is entirely nonspecific and has no diagnostic significance.

**Blood Type**

Some suggest that the single most important laboratory test in the seriously injured patient is the type and crossmatch. A number of decision rules have been suggested to determine the need for blood typing in the trauma patient, none of which has been prospectively validated. A type and screen is probably adequate for most patients who are hemodynamically stable but who remain at risk for intraabdominal injury as determined by the initial evaluation.

**Chemical**

Although often helpful, no chemical analysis needs to be routine. An increased base deficit or elevated serum lactate can be an early harbinger of hemorrhagic shock. Substantive abnormalities such as a base deficit of -6 or greater are strongly associated with the need for early transfusion, increased intensive care unit and hospital stays, and shock-related complications. However, measures of acidosis are superfluous in those in obvious shock. Conversely, the emergency clinician should never be reassured by a normal base deficit in the presence of deteriorating vital signs.

Although it would be helpful to have laboratory tests that could identify specific organ injury, this is simply wishful thinking. Although elevated serum transaminases may reflect hepatic injury, they can be falsely positive in patients with alcohol-induced liver damage. Additionally, because liver function test results are frequently negative despite hepatic trauma, they are as likely to mislead as assist in management. The situation is no better when it comes to pancreatic trauma. Serum amylase, lipase, and amylase isoenzymes all lack sensitivity and specificity. Elevated or rising levels may indicate damage, but in and of themselves are not conclusive.
Urinalysis
A visual examination of the urine can be extremely helpful for patients with significant blunt trauma. The most consistent sign of serious renal injury is gross hematuria. All patients with gross hematuria require investigation of the genitourinary system, either before laparotomy in the stable patient or after or during laparotomy for the patient with intractable shock. For the stable patient, if the urine is clear yellow on visual inspection, significant renal injury is exceedingly unlikely. Although a visual appraisal alone is adequate for the hemodynamically stable patient, a dipstick or microscopic evaluation is indicated in adults with shock.\textsuperscript{53,54} At least 1 study showed that a dipstick examination is adequate to exclude traumatic hematuria.\textsuperscript{55} Children who suffer significant trauma should undergo dipstick or microscopic analysis of the urine, as visual examination alone is inadequate.\textsuperscript{56,57}

A dipstick urinalysis or microscopic urinalysis may tip the diagnostic scales in the patient with abdominal tenderness, especially when the emergency clinician is not sure that the patient requires an abdominal CT. In 1 prospective study in adult patients who have undergone blunt trauma, the combination of a tender abdomen and microscopic hematuria was very specific for intraabdominal injury on CT (94%).\textsuperscript{58} This combination, however, was only 64% sensitive.

Radiology
Studies should be obtained only if they are likely to assist management and their benefits outweigh the risks. Chief among those risks is leaving the resuscitation area to languish in the dark and unfriendly confines of radiology. These dangers have earned the CT scanner the grim nickname “the circle of death.”

A recent article in the \textit{Annals of Emergency Medicine} attempted to identify patients who sustained blunt torso trauma but who were so low risk for intraabdominal injury that no radiological workup was warranted. The authors devised clinical prediction rules that exhibited high sensitivity and negative predictive value, as well as high levels of interobserver agreement among emergency clinicians. Obviously, reducing the number of CT scans would decrease radiation exposure and potential malignant neoplasm, the length of time in the ED, health care costs, and associated risks, such as contrast material-induced nephropathy and reactions and aspiration of oral contrast material.

During the derivation phase, 3381 abdominal CT scans were performed, and it was later determined that one-third of these were not necessary per their clinical rules.\textsuperscript{35} The prediction rule given the most weight in their study with the highest relative risk for intraabdominal injury was significant hematuria, which is incorrectly rarely used to screen for injuries other than in the genitourinary tract. The clinical rules consisted of hypotension, a GCS score less than 14, costal margin or abdominal tenderness, femur fracture, hematuria greater than 25 red blood cell (RBC)/hpf, hematocrit level less than 30%, and abnormal chest radiograph results (rib fracture, pneumothorax). Patients without any of these risk factors will have greater risks associated with abdominal CT scanning than benefit. Interestingly, flank tenderness, abdominal distention, and peritoneal irritation were considered for inclusion but were left off the list because of insufficient interobserver reliability.

Plain Radiographs
The most common radiographs ordered for the multitrauma patient consist of the chest x-ray, the anteroposterior pelvis radiograph, and the 3-view cervical spine series. The chest radiograph can help distinguish pneumothorax, hemothorax, diaphragmatic rupture, and rib fractures as well as an abnormal mediastinal contour and other signs of potential aortic disruption.

A pelvic fracture can be a significant source of blood loss. Although this study is often routine in the multitrauma patient, certain clinical criteria can safely determine its need. These clinical criteria are\textsuperscript{43}

- Unstable vital signs
- Significantly altered mental status
- Ecchymosis, swelling, laceration to the pelvis and surrounding structures
- Blood at urethral meatus, gross hematuria
- Tender pelvis, sacrum, or lower lumbar spine
- Neurologic deficit in lower extremities
- Abnormal rectal examination results (lax tone, bloody stools, abnormal prostate)
- Pain on hip movement

Abdominal plain radiographs have essentially no role in severe blunt trauma. Suggestion of significant hemoperitoneum can be seen on a supine anterior-posterior AP of the abdomen, but the sensitivity pales in comparison with DPL, US, or CT. Small quantities of readily detectable free intraperitoneal air are present in most patients with gastric, duodenal bulb, and colonic perforations but in a minority of patients with jejunal and ileal perforation. These are more readily seen on CT than plain radiographs.\textsuperscript{59}

Computed Tomography
CT is supremely capable of defining injured organs. It is most accurate for solid visceral injury. It is often able to distinguish the presence, source, and approximate quantity of intraperitoneal hemorrhage.\textsuperscript{60}

Findings On CT
The major findings on CT relate to detection of organ injury and free intraperitoneal fluid. Free fluid alone
(absent signs of organ injury) in the adult patient can be suggestive of serious disease. One retrospective study showed that exploratory laparotomy was therapeutic in 94% of patients with isolated intraperitoneal fluid on CT scan.61 Other studies support this conclusion.62

The presence of intraabdominal free air on CT is not an indication for laparotomy. This is because of the fact that free intraperitoneal air can be generated by mediastinal or pulmonary injury as well as barotrauma and thus is not pathognomonic of hollow viscus perforation.59

In contradistinction to DPL and US, CT scanning coincidentally evaluates the retroperitoneum and therefore can be helpful in the evaluation of hematuria.63 If a hemodynamically stable patient has a hemoperitoneum demonstrated by DPL or US, a subsequent CT can evaluate organ injury and assist in the decision of whether nonoperative, expectant management is appropriate.5 If CT is performed after DPL, inform the radiologist of this fact to avoid confusing residual lavage fluid with hemoperitoneum or succus.

Issues In Using CT
The value of the CT in trauma management depends on a number of variables. Patient factors include hemodynamic stability and cooperation (either voluntary or pharmacologic). Scanner issues relate to the distance the scanner is located from the ED and the generation of the machine. Helical (spiral) scanners provide faster examinations, with improved visualization of solid organs and reduced CT artifacts.64 Spiral CT may even demonstrate areas of active hemorrhage and can help predict the success (or failure) of nonoperative management.65,66 An important caveat is that the accuracy of abdominal CTs in trauma is very reader-dependent.67

The use of intravenous contrast media allows better visualization of solid organs and sharpens the distinction between normal and injured tissue. However, an oral contrast medium does not provide any significant benefit. Several studies prove that oral contrast media rarely add to diagnostic accuracy and cause considerable lengthening of the time required for study completion.68,69 One retrospective study showed that 60% of patients given oral contrast media had inadequate opacification of the gut.70

Disadvantages
The greatest hazard of CT follows from ill-advised or poorly supervised studies wherein the dynamics of illness cause stable patients to crash and unstable patients to die. In 1 large review of blunt trauma, the authors described 2 preventable deaths, both secondary to operative delay associated with obtaining an abdominal CT.71

Other disadvantages of CT include its modest sensitivity for injury of the pancreas, small bowel, and mesentery.72,73 The latter 2 are of particular concern, as hollow viscus injury may occur in approximately 5% of patients with significant blunt abdominal trauma.74 Complications, albeit uncommon, can stem from reactions to intravenous or oral contrast material.75 In addition, oral contrast material is associated with an increased likelihood of emesis, early aspiration, and pneumonia.70

The cost of CT scanning can be substantial, particularly when employed in an overly liberal fashion. In 1 prospective study, intraabdominal injuries were identified in only 11% of patients undergoing CT scans of the abdomen.58

Ultrasoundography
In the past decade, US has come to the forefront as a cornerstone study in the initial evaluation of the blunt trauma patient. Its primary role is in the detection of free intraperitoneal blood via scan of Morison’s pouch (RUQ), the splenorenal recess (LUQ), and the pouch of Douglas (pelvis), all dependent portions of the intraperitoneal cavity where blood is likely to accumulate. (See the April 2001 issue of Emergency Medicine Practice, “Emergency Imaging For The 21st Century: Where Does Ultrasound Fit In?”) The focused assessment with sonography in trauma (FAST) includes these 3 views plus a subxiphoid cardiac view for the purpose of determining hemopericardium.76

Novel positioning may increase the sensitivity of the FAST examination. One prospective observational study used increasing aliquots of lavage fluid in hemodynamically stable patients undergoing DPL. Trendelenburg positioning allowed recognition of only 400 cc of intraperitoneal fluid, compared with 700 cc in the supine position.77

US has become a necessary diagnostic tool for the trauma patient. The ability to assess hemodynamically unstable patients without moving them from the resuscitation bay has lifesaving potential. In an attempt to diagnose hollow viscus injury, 289 patients sustaining severe torso blunt trauma and 195 patients with severe abdominal pain were assessed for intra peritoneal free air. The sensitivity of gastrointestinal perforation by US was 85.7% (free air visualized in 46 of 54 patients) and the specificity was 99.6%.78 Three of the 8 patients missed by US did not have free air on their CT. The major caveat to this study was that the practitioners performing the examinations had been using US for more than 5 years and were comfortable with abdominal examinations.

Free air was diagnosed if a high-echoic spot or area with hyperechoic tail was detected in the ventral space of the liver, which was easily movable and changed its image with compression. This study supports the need for emergency clinicians to become skilled at identifying free air with US. It is a useful adjunct to CT, especially when free air is visu-
alized on the CT adjacent to the diaphragm, which could be a false-positive result. Two patients in the study had a false-positive CT finding; however, free air was not seen with US. Having this modality can reduce the number of unnecessary laparotomies because of false-positives on the CT scan.

**Advantages**

US has many advantages. First of all, it is accurate. A recent study examined 2576 patients who underwent US for blunt abdominal trauma. Fewer than 2% had a false-negative examination. Overall, US had a sensitivity of 86%, a specificity of 98%, and an accuracy of 97% for detection of intraabdominal injuries.\(^7\) One study showed that in the hypotensive patient with blunt abdominal trauma, US is 100% sensitive and specific.\(^8\)

The instrument is portable and routinely housed in the trauma resuscitation room and can accomplish the FAST examination in fewer than 5 minutes. Sensitivity for detection of as little as 100 mL, but more typically 500 mL, of intraperitoneal fluid ranges from 60% to 95%, with excellent specificity.\(^9\)

US can replace DPL in rapidly answering the key question of whether hemoperitoneum is present. In contrast to DPL, US can also evaluate the mediastinum, is not invasive, and can be performed repeatedly by multiple individuals. In contrast to CT, it poses no radiation or contrast material hazard, and usage is not restricted to radiologists. Accuracy of performance is correlated with length of training and experience, but competence can readily be acquired. In 1 study, emergency clinicians were able to detect hemoperitoneum more than 90% of the time after only 2 hours of training (1 hour, theory; 1 hour, practical).\(^10\) All in all, US provides a relatively accurate, rapid, safe, and less expensive diagnostic screening tool.\(^11\)

**Limitations**

It is important to understand that, in the United States at least, US is not used to image solid parenchymal damage, the retroperitoneum, or the diaphragm. Technical difficulties can occur in obese patients, as well as those with a great deal of bowel gas or subcutaneous emphysema. In general, US is less sensitive than DPL for the presence of hemoperitoneum. Like DPL, US is insensitive when there is organ injury but no free intraperitoneal blood, as in subcapsular hematoma of the spleen. In 1 retrospective review, surgical or angiographic intervention (or both) was required in 26 patients (17%) without hemoperitoneum; such patients would be expected to have a FAST exam with negative results.\(^12\)

FAST has dramatically improved ED throughput time for patients with blunt abdominal trauma. The first sonography outcomes assessment program trial (SOAP-1) revealed the median time till the OR was reduced significantly in the US group (60 min from 157 min).\(^13\) This fact alone should motivate all emergency clinicians to become sufficiently skilled at FAST, a feat that takes approximately 2 hours.\(^14\)

An important aspect of FAST is that it is a good "rule in" test with a likelihood ratio of 86 for tests with positive findings. The negative predictive value of 0.98 makes it a useful screening tool to rule out patients as well.\(^15\)

However, a potentially problematic issue with FAST scans is that its goal is confusing. FAST is not used to detect intraabdominal organ injury but rather the bleeding that is often secondary to an injured abdominal organ. Thus, although there may be an injury, FAST will only be diagnostic if there is resulting bleeding. When there is not a significant amount of bleeding or fluid, which often occurs in bowel, mesenteric, and diaphragmatic injuries, the FAST examination will have negative results. Most studies suggest that 250 to 620 mL of fluid must accumulate before FAST can be diagnostic.\(^16\) Although less fluid is needed if the patient is placed in the Trendelenburg position. Second, it can take some time for a significant amount of blood to accumulate after an injury. Thus, to ensure that there is no intraperitoneal fluid in a patient based solely on sonography, FAST should be repeated 4 to 6 hours after the initial scan.\(^17\)

Although performing the FAST before enough fluid has accumulated can lead to a false-negative test, waiting too long can lead to the same result. If too much time has elapsed, blood can clot and appear hyperechoic or isoechoic, making recognition difficult. Additionally, an empty bladder can lead to missing free fluid in the pelvis, resulting in a false-negative scan. If a foley is inserted before the FAST examination or if it is necessary to repeat the FAST, the emergency clinician can irrigate saline through the foley to refill the bladder provided that there are no contraindications.\(^18\)

As is often true for CT, US often fails to recognize bowel injury, but relies on the visualization of small amounts of intraperitoneal fluid. Studies show that the majority of patients with isolated bowel and mesenteric injury have a negative US of the abdomen.\(^19\)

**Miscellaneous**

Angiography is an invasive and time-consuming procedure. Its use is generally restricted to 2 instances. Most often, it is employed as a diagnostic and therapeutic agent for bleeding pelvic vessels. Occasionally, in selected centers, it is used to detect and embolize actively bleeding intraparenchymal vessels (usually in the spleen).\(^20\) In patients for whom pancreatic injury is suspected, endoscopic retrograde cholangiopancreaticoduodenography (ERCP) is used to evaluate the ductal system.\(^21\)
Diagnostic Peritoneal Lavage
After nearly 40 years, DPL remains a valued tool in abdominal trauma. It entails 2 steps. First is the attempted aspiration of free intraperitoneal blood (known as peritoneal aspiration or peritoneal tap). Second is the lavage portion, in which fluid is used to wash the peritoneal cavity then is recovered by gravity drainage and subsequently analyzed.

Advantages
The signal virtue of DPL is in the multiple trauma patient with hemodynamic instability. DPL, like US, can promptly discover or refute the presence of intraperitoneal hemorrhage. It is sensitive to bowel perforations, where other diagnostic tests (CT, US) often fail. It is especially valuable in patients who are poor candidates for ongoing clinical evaluation because of severe head injury, for example (see Table 1).

DPL And Pelvic Fractures
The prevalence of false-positive peritoneal lavage in pelvic fracture is as high as 29%. Therefore, authorities recommend an open supraumbilical approach to avoid transgressing a preperitoneal hematoma that has dissected out of the pelvis to the anterior abdominal wall. It is estimated that a lag of at least 2 hours is required before this dissection can occur, but the accuracy of this in humans is unknown. In the hemodynamically stable patient with a pelvic fracture, a DPL with positive results by red cell criteria should ordinarily prompt CT to better define the need for laparotomy.

Techniques
DPL can be conducted by closed (Seldinger technique), semiopen, or open technique. Relative contraindications to DPL include a prior midline surgical procedure, history of significant intraperitoneal infection, coagulopathy, obesity, or second or third trimester of pregnancy. However, any of these can be overcome when necessary.

The open method is the most arduous and is reserved for circumstances in which the other techniques have failed or are deemed unsafe, as in the presence of pelvic fracture, pregnancy, obesity, or a prior abdominal surgical procedure. (See Table 2.) However, the reputed advantages of the open technique for some of these conditions may be overstated. In a retrospective review, the authors found that “the complication rate and accuracy of closed DPL in patients with previous abdominal surgery were similar to those for DPL performed in patients without previous abdominal surgery.”

In a prospective study comparing the closed with the open technique, the authors found that

Table 1. Clinical Purpose Of Diagnostic Peritoneal Lavage Following Blunt Mechanism

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Circumstance</th>
<th>Alternate or Complementary Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapidly determine presence of intraperitoneal hemorrhage</td>
<td>Multiple blunt trauma, hemodynamically unstable</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Determine presence of intraperitoneal organ injury</td>
<td>Suspected or known blunt trauma with unreliable examination</td>
<td>CT</td>
</tr>
<tr>
<td>Determine presence of intraperitoneal hemorrhage or injury</td>
<td>Multiple trauma patients who require general anesthesis or lengthy diagnostic studies for other injuries</td>
<td>CT, ultrasound</td>
</tr>
</tbody>
</table>


Table 2. Preferred Site Of Diagnostic Peritoneal Lavage

<table>
<thead>
<tr>
<th>Clinical Circumstance</th>
<th>Site</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard adult</td>
<td>Infraumbilical midline</td>
<td>Closed or semi-open</td>
</tr>
<tr>
<td>Standard pediatric</td>
<td>Infraumbilical midline</td>
<td>Closed or semi-open</td>
</tr>
<tr>
<td>Second- and third-trimester pregnancy</td>
<td>Supra-uterine</td>
<td>Fully open</td>
</tr>
<tr>
<td>Midsline scarring</td>
<td>Left lower quadrant*</td>
<td>Fully open*</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>Supra-umbilical*</td>
<td>Fully open*</td>
</tr>
</tbody>
</table>

*Empirical data to support these recommendations are limited.

the closed peritoneal lavage was superior to open lavage in abdominal trauma; it was faster, easier to use, less expensive, and as safe as open lavage. A recent meta-analysis examined all of the prospective, randomized, controlled trials comparing the closed with the open technique of DPL. In this analysis, the closed DPL technique was as accurate and safe as the standard open DPL technique.

**Interpretation**

The aspiration of at least 10 cc of blood has a positive predictive value of greater than 90% for intraperitoneal injury, typically solid visceral or vascular. This finding is responsible for approximately 80% of true positive DPLs in blunt trauma. The RBC count threshold for lavage effluent is set at 100,000/cc. Other laboratory parameters of DPL are less useful. A white blood cell (WBC) count exceeding 500/cc can herald hollow viscus injury but tends to lag this by 3 to 6 hours and is often nonspecific. Elevated lavage amylase and alkaline phosphatase, particularly the former, have been demonstrated in the immediate postinjury period following small intestinal injury. Bile staining and Gram’s staining of lavage fluid lack accuracy such that their routine use is proscribed.

The volume of returned lavage fluid may be important. One study showed that in patients suffering blunt abdominal trauma, the RBC count of DPL fluid regularly increases as more fluid is recovered. The authors suggest collecting at least 600 cc of effluent to avoid a false-negative lavage.

**Limitations**

On the one hand, thanks to the exquisite sensitivity of DPL for blood, the threshold of 100,000 RBC/cc can produce unnecessary laparotomy for trivial injury, typically to the spleen or liver. On the other hand, injury to certain structures — notably the bowel and the diaphragm — produces limited hemorrhage, such that RBC counts of 20,000 to 100,000 RBC/cc should be considered carefully in clinical context and for an observation period of 12 to 24 hours.

DPL has very limited utility in today’s era of diagnostic tools as long as US and CT are easily accessible. Its value remains in diagnosing hollow viscus injury and obviating the need for laparotomy in hemodynamically stable patients with free fluid found on CT scan but without evidence of solid organ injury. These latter patients can be treated nonoperatively, and once practitioners learn to use each of these diagnostic resources together, nontherapeutic laparotomies should become very rare.

**Laparoscopy**

Laparoscopy has been most useful in assessing penetrating trauma; however, very little experience has been acquired in the setting of blunt trauma.

**Nasogastric Tube**

Penetrating trauma to the epigastrium, left upper quadrant, or low chest may result in gastroduodenal hemorrhage and result in positive aspiration by nasogastric tube placement. In severe blunt trauma, gastric perforation from sudden and severe forces can occur but is very uncommon. This will result in free intraperitoneal air and possibly intragastric bleeding. Otherwise, nasogastric tube placement may be useful for the evacuation of gastric air and contents in the supine patient, particularly one about to be intubated (although Sellick’s maneuver should suffice).

**Management**

**General**

The real crux of abdominal trauma management lies first in the suspicion of injury and then in the use of the best diagnostic tools. Appropriate and timely consultation of a surgeon, when necessary, is a vitally important ED intervention. Unlike penetrating trauma, laparotomy for blunt mechanism is rarely mandated solely by clinical parameters. Relative clinical indications for laparotomy are found in Table 3. Blunt trauma patients typically have numerous potential sources of blood loss, both intra- and extra-abdominal. This can complicate the decision to operate on the abdomen. Furthermore, reliance on physical examination alone can be precarious for many reasons, including altered mental status, paralysis, and altered sensation.

<table>
<thead>
<tr>
<th>Manifestation</th>
<th>Pitfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable vital signs with strongly suspected abdominal injury</td>
<td>Alternate sources shock</td>
</tr>
<tr>
<td>Unequivocal peritoneal irritation</td>
<td>Unreliable</td>
</tr>
<tr>
<td>Pneumoperitoneum</td>
<td>Insensitive and non-specific: may be due to cardiopulmonary source or invasive procedures (DPL, laparoscopy)</td>
</tr>
<tr>
<td>Evidence of diaphragmatic injury</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>Significant gastrointestinal bleeding</td>
<td>Uncommon, unknown accuracy</td>
</tr>
</tbody>
</table>

**Table 3. Clinical Indications For Laparotomy Following Blunt Trauma**
This conundrum is profound. Rushing a patient to what proves to be a nontherapeutic laparotomy leads to delay in more vital diagnostic and therapeutic undertakings. Alternatively, failure to determine the need for exigent laparotomy has even more grave consequences. Thus, in multijystem blunt abdominal trauma, diagnostic studies (DPL, US, CT) are frequently indicated. (See Table 4.)

Traditional indications for diagnostic tests include:

- Suspected intraabdominal injury
- Equivocal abdominal examination
- Altered sensorium due to drugs, alcohol, or head trauma
- Distracting injury
- Spinal cord injury with abdominal anesthesia
- Unexplained hypotension
- Multiple trauma patients who must undergo general anesthesia for orthopedic, neurosurgical, or other injuries

These criteria have not been subjected to rigorous prospective examination. Several retrospective studies suggest that repeated physical examination in the intoxicated patient with a relatively normal mental status is generally reliable. For instance, one study retrospectively examined a cohort of intoxicated but hemodynamically stable and alert patients to determine the need for abdominal testing (CT, US, or DPL) before an emergent extraabdominal surgical procedure. All patients had a GCS of 14 or greater and an abdominal physical examination with negative findings. Only 3 (1.4%) intraperitoneal injuries were diagnosed in the study population; 2 of these were stable grade I liver injuries, and 1 was a missed diaphragmatic injury diagnosed the day after admission.

Another retrospective investigation examined the utility of physical examination in detecting intraabdominal injury in intoxicated blunt trauma patients. All study patients had a blood alcohol level of 80 mg/dL or greater, a GCS score of 15, and an unremarkable abdominal examination. In only 2 (0.6%) patients did physical examination miss an injury requiring abdominal exploration. The authors found a significant association between major chest injury and abdominal injury and concluded that physical examination and attention to clinical risk factors allow accurate abdominal evaluation without CT.

As both of the above-mentioned studies were retrospective, further evaluation of who needs abdominal evaluation is required.

### Management Schemata

A small minority of patients undergo laparotomy based on clinical indicators alone. For the remainder, abdominal trauma can be categorized at the primary level by whether the patient is hemodynamically stable or unstable. (See Table 4.) Within these 2 possibilities is a second level of staging based on other urgent concerns or “special circumstances” that coexist with the possibility of intraperitoneal injuries. (See “Clinical Pathway: Management Of Blunt Abdominal Trauma.”)

### Hemodynamically Unstable

In the multiple blunt trauma patient in shock, 3 cavities — the thoracic, abdominal, and retroperitoneal

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**Table 4. Diagnostic Studies In Blunt Abdominal Trauma**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Study Purpose</th>
<th>Primary Study</th>
<th>Alternate/Compensatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemodynamically unstable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>Intraperitoneal hemorrhage</td>
<td>DPL, US</td>
<td>—</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>Intraperitoneal hemorrhage</td>
<td>DPL,* US</td>
<td>—</td>
</tr>
<tr>
<td>Hemodynamically stable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>Organ injury&lt;sup&gt;1&lt;/sup&gt;</td>
<td>CT</td>
<td>DPL, US&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nonoperative management&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Organ injury</td>
<td>CT&lt;sup&gt;+&lt;/sup&gt;</td>
<td>DPL,** US&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Closed-head injury</td>
<td>Organ injury, hollow viscus injury</td>
<td>DPL,** CT&lt;sup&gt;4&lt;/sup&gt;</td>
<td>US&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Blunt aortic disruption</td>
<td>Intraperitoneal hemorrhage</td>
<td>DPL, US</td>
<td>CT&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Positive peritoneal aspirate mandates laparotomy; positive RBC count only warrants attention to pelvic fracture.

<sup>1</sup> Specific organ damage or fluid/blood suggesting injury.

<sup>2</sup> US for organ injury much less reliable than for intraperitoneal hemorrhage.

<sup>3</sup> Institutional capability should be carefully considered.

<sup>4</sup> CT less reliable for hollow viscus than for solid visceral injury.

<sup>5</sup> Complementary to CT if hollow viscous suspected.

<sup>12</sup> May be more appropriate if can be rapidly acquired or if CT primary study for blunt aortic disruption.

DPL: Diagnostic peritoneal lavage
US: Ultrasound
CT: Computed tomography
— warrant immediate attention. Clinical examination and chest x-ray will identify blood in the thoracic space or suggest the presence of blunt aortic disruption (BAD). The pelvis radiograph, if positive for significant disruption, can predict a retroperitoneal hemorrhage.

The third space, the peritoneal cavity, should be targeted by peritoneal aspiration or US to reveal or exclude the presence of blood. A positive study in a clinically unstable patient mandates laparotomy. The unstable patient is not a candidate for CT scanning.

The unstable patient with a hemoperitoneum needs to be moving to the OR or to another hospital for laparotomy (if local facilities are unavailable). While the patient is being “packaged for transport” to either of these locations, the emergency clinician may treat the patient with fluids and blood. Predictors of need for transfusion include:

- Shock
- Hematocrit less than 30%
- Observed blood loss of at least 500 cc or grossly visible gastrointestinal bleeding
- Emergency operation with anticipated blood loss
- Prehospital systolic blood pressure less than 100 mm Hg
- A base deficit more negative than -6

Hemodynamically Stable

In this circumstance, CT scanning is widely preferred as it can specify organ damage, assess hemoperitoneum, and evaluate nonabdominal body regions. In a stable patient, positive findings on CT do not necessarily mandate laparotomy. Rather, expectant treatment can be accomplished in select patients with low to moderate grades of liver or spleen trauma. In such cases the patient should be otherwise normal (eg, absent coagulopathy), and the center should be able to provide adequate monitoring and support. The ideal candidate for CT would have normal sensorium and minor to intermediate severity of mechanism.

Treating pain is an important part of caring for the trauma patient. Caution should be exercised in the administration of analgesics and sedative-hypnotics to patients being observed for intraperitoneal injury. As there are no prospective data on the matter, usage of these medications must be judicious to optimize recognition of symptoms by the patient and signs by the care provider.

There are pitfalls in expectant management. First, coincident hollow visceral injury that is not detected by CT can lead to disastrous consequences (see subsequent section). Second, expectant management tends to lead to increased use of blood products. Finally, should this approach fail, the lag from injury to operation lengthens, with a resultant increase in morbidity, fatality, and the likelihood of organ resection.

The role of US in the hemodynamically stable patient is less clear. If the patient has a relatively benign abdominal examination, normal initial US results are likewise reassuring. Such a patient may be followed with serial physical examinations and possibly serial US without the use of CT. This strategy is best suited to those who have suffered a mild to moderate mechanism of injury, have a normal sensorium, and have no significant distracting injuries. The question then becomes “Which stable patient deserves ED US?” (as opposed to simply undergoing serial physical examinations).

Although treatment of hemodynamically unstable patients with positive FAST examinations is quite clear, the same cannot be said for stable patients with positive FAST. A study in the Journal of Emergency Medicine performed a retrospective cohort looking at normotensive blunt trauma patients with positive FAST examinations. Thirty-seven percent of these patients required a therapeutic laparotomy compared with 0.5% with a FAST examination with negative results.

Thus the study recommends performing FAST examinations on all normotensive blunt trauma patients to risk-stratify them. Practitioners need to be aware of the strong association between therapeutic laparotomy and positive FAST results in normotensive blunt trauma patients and aware of the exceedingly unlikely need for a laparotomy in these patients with a negative FAST results.

There has been considerable research on management to avoid unnecessary laparotomies and their associated cost. One multicenter study examined different management and evaluation strategies of asymptomatic patients with abdominal stab wounds. Although this is not blunt abdominal trauma, the study has applicability to the current topic. Of 278 patients, only 61 (22%) who did not have an immediate reason for surgical exploration (shock, evisceration, and peritonitis) received a therapeutic laparotomy. Obviously patients exhibiting shock or intestinal evisceration need immediate laparotomies: 88% of patients in shock and 100% of patients with intestinal evisceration had therapeutic laparotomies.

In patients with peritonitis as their only finding, 29% had laparotomies with negative results. This high rate is explained by peritonitis being a fairly subjective criterion for laparotomy. Interestingly, 81% of patients with diffuse peritonitis had therapeutic laparotomies compared with 50% of patients with local peritonitis. Thus, practitioners need to become better at differentiating true peritoneal signs from physical signs related to an abdominal wound or point of impact.

FAST has less benefit in patients with penetrating abdominal wounds than those with blunt trauma. FAST guided decision-making in only 4% of the participants in this study. Hemoperitoneum does not necessarily correlate well with injuries requir-
ing operative interventions. Ten of 36 patients with abnormal FAST examination results had negative laparotomies, and 23% of patients with normal FAST results ultimately had a therapeutic laparotomy. The study concluded that normal FAST results should not be the primary factor in safely discharging patients from the ED. CT’s downside is that results can be misleading: 46 asymptomatic patients found to have abnormal findings were taken to the OR and 24% of them had nontherapeutic laparotomies.

Of the remaining 35 patients with surgical therapy, 18 only had solid organ injuries or fascial defects that could have been managed nonoperatively. Thus, like FAST, although CT scan does reveal evidence of intraperitoneal fluid, the significance of the findings is at times unclear. Consequently, CT scan should not be the lone factor in determining the need for surgical exploration.

The study concludes that without hard signs of significant intraabdominal injury such as shock, evisceration, and generalized peritonitis, diagnostic tests in the remaining patients are associated with a substantial number of nontherapeutic laparotomies and extensive, unnecessary costs. None of these diagnostic examinations fared better than the others in determining the need for therapeutic laparotomies. The only test to limit hospital admissions was local wound exploration for peritoneal cavity penetration. If there was peritoneal penetration, then the patient should be monitored with serial examinations for decompensation.

**Suspected Bowel Injury**

The patient with suspected bowel injury provides a significant diagnostic challenge. Delayed or missed diagnosis can result in considerable morbidity or mortality. In 1 series of patients with hollow viscus injury, delays in the diagnosis were directly responsible for almost half of the deaths. Even delays as little as 8 hours result in significant morbidity and mortality.

There is also great debate as to the study of choice in patients likely to have hollow visceral injury, especially those with a seat belt sign. In 1 prospective study, 36% of patients with a seat belt sign required operative intervention, most of whom had small bowel perforation. In this series, DPL was 100% sensitive for the diagnosis of intestinal perforation (5 of 5 patients), whereas the initial CT scan was only 33% sensitive. In another study examining the prospective CT diagnosis of bowel injury, CT had a sensitivity of 64%, an accuracy of 82%, and a specificity of 97%. These and other articles have led some to suggest that patients with a seat belt sign need a study other than CT to rule out intestinal injury.

However, a recent review regarding the use of CT in this situation is more sanguine. In this review, the authors searched MEDLINE between 1980 and 1998 to evaluate the performance of DPL and CT in detecting blunt gastrointestinal tract injuries. They state that when expert interpretation is available, CT is accurate in detecting hollow viscus injury as long as unexplained free fluid, bowel wall thickening or enhancement, mesenteric fat streaking, and bowel dilatation are assumed to represent injury. If the scan quality is suboptimal or expert interpretation is unavailable, the authors recommend DPL.

Solid organ injury is much more common than hollow viscous injury (HVI), constituting 95% of significant injuries in blunt abdominal trauma. The prevalence of HVI in blunt trauma is only approximately 1%. Interestingly, it occurs much more frequently when multiple solid organs are injured than when just 1 organ is injured severely. Patients with multiple intraabdominal injuries had a 6.7 higher risk of additionally having HVI than did patients with a single solid organ injury.

McStay wrote a recent review about appropriate management of HVI, citing that although seat belt marks, abdominal wall ecchymosis, distention, and vomiting are all associated with viscus injury, the accuracy and positive predictive value of these signs are low. Gross blood on rectal examinations increases the probability of viscus injury, but in general, the physical examination is notoriously inaccurate.

Although free air on a chest x-ray would indicate to practitioners the need for a therapeutic laparotomy in patients sustaining bowel injury, free air is rarely visualized in supine trauma patients. Thus there is need to rely on definitive diagnostic testing to rule out bowel injury in all patients with blunt abdominal trauma. Although FAST has a high sensitivity and specificity for intraabdominal injuries, the examination relies on the presence of 250 to 620 cc of free fluid, as mentioned previously. Unfortunately, the sensitivity for viscus injury is much lower, as that much free fluid is rarely found following viscus injury.

The newest data on CT scanning reveals sensitivities for bowel injuries of 83% to 94% and accuracies of 84% to 99%. A study in 2004 retrospectively assessed 1082 patients with blunt abdominal trauma with noncontrast abdominal CT, revealing a sensitivity of 82% and specificity of 99% for HVI. Unfortunately, concurrent solid organ injury can mask CT findings of HVI that delays diagnosis and increases morbidity and fatality. Controversy exists about the need for oral contrast material and potential adverse effects of aspiration and delays in scanning, and there is still no general consensus.

Extraluminal gas or oral contrast material or intraluminal content, intramural air, or discontinuity of the bowel wall can appear following full thickness bowel injury and signify the need for emergent surgical exploration; but these findings are not always present. Mesenteric hematomas and hemoperitoneum are nonspecific and highlight the trouble with CT in that the significance of findings is at times unclear.

One retrospective study of patients with free fluid and no solid organ injury seen by FAST and CT
found that 76% of these patients had viscus injury when taken to the OR.\textsuperscript{112} However, that is a high rate of nontherapeutic laparotomies. Additionally, Livingston found only a 7% association between free fluid without evidence of organ injury and bowel injury.\textsuperscript{112} His work recommended the more cost-efficient method of management: observation and serial examinations.

Multidetector CT has made scanning more rapid, lowering the risk in moving unstable patients to the CT suite, as there is less time for patients to decompensate. Increased sensitivity is another feature resulting from thinner sections and reduced motion artifacts, leading to higher resolution and 3-dimensional images.

One retrospective review reported that CT diagnosed 85 out of 87 hollow viscus injuries. The review concluded that the CT was adequately sensitive to rule out HVI.\textsuperscript{112} However, a much larger study that enrolled 2632 patients reported a false-negative rate of 13% and expressed caution about solely relying on CT scans to rule out viscus injury.\textsuperscript{112} As mentioned, a delay of as little as 6 to 8 hours can result in bile or intestinal contamination and sepsis and severely high fatality rates. The American College of Emergency Physicians Clinical Policy statement in 2004 reports that CT alone cannot reliably exclude hollow viscus, diaphragmatic, or pancreatic injury.\textsuperscript{117}

The incidence of traumatic viscus injury is so low that it is difficult for practitioners to get accustomed to diagnosing and managing it. To date, no diagnostic model with high sensitivity and specificity exists to guide practitioners in discharging patients after blunt abdominal trauma with imaging, with negative results. McStay’s article recommends dividing patients into high risk (severe mechanism, significant abdominal tenderness, seat belt sign or ecchymoses, gross hematuria, free air on chest x-ray) and low risk (no significant injuries, low-risk mechanism, no tenderness in a reliable patient). In high-risk patients with no radiographic findings, admission for observation is encouraged, whereas discharge is safe in low-risk patients.\textsuperscript{112}

### Special Circumstances

**Missed Injuries**

Missed injury is common in trauma management. As many as 25% of seriously injured trauma patients have at least 1 injury that is overlooked during the initial evaluation.\textsuperscript{118, 119} Missed injuries are most common in patients who have altered mental status, those who are intubated, and those who need an immediate operation.\textsuperscript{120, 121}

Although the most frequently missed injuries are orthopedic,\textsuperscript{122-124} missed abdominal injury is far more lethal. In fact, missed intraabdominal injury is the most common preventable cause of trauma deaths.\textsuperscript{125}

Distracting injury is so called as the patient, the emergency clinician, or both are...well...distracted. Distracting injury is one of those concepts all of us understand but none of us can quantify. However, it must be appreciated, as it is well known to cause missed abdominal as well as cervical spine injuries. In a recent prospective study, 7% of patients with no abdominal pain or tenderness but with distracting extraabdominal injury were found to have intraabdominal injury.\textsuperscript{126}

Patients with altered mental status are also at high risk for undetected/unsuspected abdominal injury. Nearly 10% of patients with suspected “isolated” head injury may have intraabdominal findings.\textsuperscript{127} In a different retrospective study of comatose but normotensive trauma patients, the use of clinical signs alone resulted in more missed injuries than did using an objective test (in this study, DPL).\textsuperscript{27} The authors suggested that all unconscious blunt trauma patients undergo objective testing of the abdomen to avoid missing life-threatening injuries.

### Multisystem Injury

In patients with more than 1 critically injured bodily system, a rigid management algorithm does not and should not exist. In these situations, the decision making needs to be fluid and responsive to the minute-to-minute changes of the patient.

It is correct that active and substantive intraperitoneal hemorrhage in an unstable patient demands immediate attention — specifically, lifesaving laparotomy. However, a patient can have a minor splenic injury with evidence of hemorrhage on US, DPL, CT, or some combination of tests, yet other demands (such as an unstable pelvic fracture) will be greater at that point in time. Likewise, certain intraperitoneal injuries, such as a perforated jejunal, require operation, but a delay of at least 8 hours is acceptable while more pressing concerns are addressed.

In summary, the key point is that an unstable patient with a significant hemoperitoneum must undergo laparotomy or face imminent exsanguination.

### Pelvic Fracture

An unstable patient with a significant pelvic fracture and bloody peritoneal aspirate or positive US finding must proceed to emergency laparotomy. (See “Clinical Pathway: Management Of Combined Pelvic Fracture And Abdominal Trauma.”) This is because approximately 85% of such patients will have active intraperitoneal hemorrhage at laparotomy. Some unstable patients with severe pelvic fracture will demonstrate an US and/or a negative peritoneal aspirate with normal findings. Barring other nonabdominal sources, the presumed origin of shock is the retroperitoneum. Therefore, the patient would then proceed to angiography for possible embolization to staunch hemorrhage.
Clinical Pathway: Management Of Blunt Abdominal Trauma

Blunt abdominal trauma mechanism

Clinical mandate for laparotomy?

Laparotomy (Class II)

Hemodynamically unstable?

Intraperitoneal hemorrhage?

DPL, US† (Class II)

Intraperitoneal injury?‡
- CT (Class II)
- DPL (Class II)
- Serial physical examinations; with or without ED US (Class II)

Injury requires laparotomy?§

Laparotomy (Class II)

Observe (Class II)

Discharge (Class II)

* Can be unreliable because of closed-head injury, intoxicants, distracting injury, or spinal cord injury.
† Determined by unequivocal free intraperitoneal fluid on ultrasound or positive peritoneal aspiration on DPL.
‡ One or more studies may be indicated.
§ Need for laparotomy is based on clinical scenario, diagnostic studies, and institutional resources.

For Class of Evidence Definitions, see page 1.
* Determined by unequivocal free intraperitoneal fluid on ultrasound or positive peritoneal aspiration on DPL.
† One or more studies may be indicated.
‡ Need for laparotomy is based on clinical scenario, diagnostic studies, and institutional resources.

For Class of Evidence Definitions, see page 1.
Clinical Pathway: Management Of Combined Head And Abdominal Trauma

Head injury

Management of airway and intracranial pressure (Class II)

Hemodynamically unstable?

YES

Hemoperitoneum?*

POSITIVE

Lateralizing signs?

YES

Laparotomy\(^a\) (Class II)
Consider head CT\(^b\) (Class II)

NO

Laparotomy (Class II)

Head CT (Class II)

NEGATIVE

Lateralizing signs?

YES

Head CT or craniotomy\(^d\) (Class II)

• Head and abdominal CT (Class II)
• Continue resuscitation (Class II)
• Manage intracranial pressure (Class II)

NO

Abdominal CT, DPL\(^e\) (Class II)

Lateralizing signs?

YES

Head CT or craniotomy\(^d\) (Class II)

NO

Abdominal CT, DPL\(^e\) (Class II)

* Based on ultrasound, diagnostic peritoneal aspiration, or both.
\(^b\) Consider pre-laparotomy head CT based on clinical picture and availability of CT.
\(^d\) Burr holes or craniotomy based on clinical picture and availability of CT.
\(^e\) DPL can be complementary to CT in determining hollow viscus injury.
\(^a\) Consider burr holes or craniotomy simultaneous with laparotomy.

For Class of Evidence Definitions, see page 1.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Clinical Pathway: Management Of Combined Wide Mediastinum And Abdominal Trauma

Wide mediastinum*

Initial resuscitation (Class II)

Hemodynamically unstable?

**YES**

Hemoperitoneum?†

**POSITIVE**

Laparotomy (Class II)
  - Left lateral thoracotomy if rupture suspected‡ (Class II)
  - Consider intraoperative transesophageal echocardiogram or aortogram (Class II)

**NEGATIVE**

Helical CT of chest and abdomen (Class II)

**NO**

Helical CT of chest and abdomen (Class II)

* Preferably based on upright PA film and mechanism of injury.
† Based on ultrasound, diagnostic peritoneal aspirate or both.
‡ Allows surgical access to majority of disruption sites.

For Class of Evidence Definitions, see page 1.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Before proceeding to angiography, a pelvic-stabilizing device is indicated to reduce pelvic volume, stabilize displaced fracture segments, and tamponade venous bleed. The PASG, vacuum splint, or even a tightly wrapped sheet about the pelvis when necessary can serve in this capacity.\textsuperscript{16} The placement of an external fixator, typically by an orthopedist, is advised by some.\textsuperscript{128} However, this requires a much more laborious application, and there are no prospective, randomized trials to support its use.

In a patient with pelvic fracture and apparent hemodynamic stability, a CT of the abdomen is usually warranted. If an US was performed and demonstrated some measure of fluid, CT can help decipher the need for laparotomy. If DPL effluent returns with a positive RBC count result only (but a negatively resulting aspirate), CT should again be used to establish whether significant intraperitoneal injury exists, as the RBC count alone in this circumstance can be falsely positive.

**Closed Head Injury**

Patients with surgically correctable injuries of both the head and the abdomen are rare, although the literature is divided regarding which injury is more common in the comatose hypotensive patient.\textsuperscript{129,130} The presence or absence of lateralizing findings (such as a unilateral blown pupil or asymmetric posturing) is key. Generally speaking, patients with severe closed head injury but without lateralizing findings do not require craniotomy.\textsuperscript{130} Should lateralizing features and blunt abdominal injury coexist, the clinician is faced with the choice of rapid prelaparotomy CT scan of the head versus preemptive burr

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**Risk Management Pitfalls For Blunt Abdominal Trauma** (Continued on page 86)

1. “We thought the hypotension was caused by head injury, not abdominal trauma.”
   Not so — with few exceptions. First, the infant with cephalohematoma, intracranial hemorrhage, or both, can house sufficient blood in those spaces to cause hemorrhagic shock. Second, patients in the agonal phase of severe closed-head injury may demonstrate hypotension. This is simply a pre-terminal event.

2. “Hey, the abdomen was definitely soft and nontender on my exam, and even the bowel sounds were normal.”
   Many factors can confound the patient’s ability to sense pain and the physician’s skill in determining tenderness. These include distracting injury, altered sensorium, and spinal cord injury. Even in the alert patient without confounders, false-positive and false-negative examinations can still occur. When the mechanism is worrisome and the patient cannot be reliably examined and re-examined, abdominal diagnostic studies are in order. As far as the bowel sounds are concerned, that’s a definite “so what?”

3. “You can’t perform DPL in pregnant women.”
   Yes, you can, but the technique may have to be modified. In the first trimester, no alteration is necessary. In the second and third trimesters, as the uterus has risen out of the protective confines of the pelvis, an open and supra-uterine technique should be utilized. The interpretation of peritoneal aspiration and DPL fluid is unchanged. Ultrasound, of course, is an acceptable alternative.

4. “The patient had a horrible pelvic fracture, and we knew external fixation and angiography were the only steps that could save him.”
   In some cases, that may well be true. However, when pelvic fracture is present, intraperitoneal hemorrhage is frequently present as well. The abdomen should be assessed in all cases of pelvic fracture. In the unstable patient, ultrasound or DPL is indicated to rapidly determine whether there is intraperitoneal hemorrhage. If there is significant hemoperitoneum on ultrasound or a positive aspirate on DPL (not simply a positive lavage), urgent laparotomy is indicated prior to angiography.

5. “We screened our patient with our standard measures: hematocrit, urinalysis, and chest and abdominal films. They were all normal.”
   Unfortunately, you did the wrong tests. The hematocrit is not used as a marker for the presence of intraperitoneal trauma. Serum amylase and lipase, and amylase isoenzymes, have very low positive predictive value for pancreaticoduodenal injury. Plain films of the abdomen are practically of historical interest only. The discovery of free intraperitoneal injury by these can be useful, but sensitivity and specificity are so incredibly low in comparison with US, DPL, and CT that this film is not routinely obtained.

6. “Sure, the radiology department is one floor above our ED. But CT is a much better test than US.”
   The statement that CT is superior to US for definition of intraperitoneal organ injury is absolute-
holes in the ED or during laparotomy. (See “Clinical Pathway: Management Of Combined Head And Abdominal Trauma.”)

Neurosurgeons prefer the former approach whenever possible, but hemodynamic instability may compel the latter. The emergency clinician sorting this out must measure the timeliness of CT availability, when the neurosurgeon is expected to arrive, and, most importantly, the severity and direction of hemodynamic changes.

One study suggests that patients with hemothorax and lateralizing signs are candidates for emergent head CT only if their blood pressure stabilizes with fluids or blood. However, immediate laparotomy is indicated in patients who remain hemodynamically unstable.

Blunt Aortic Disruption
Potential BAD presents even more controversies. (See “Clinical Pathway: Management Of Combined Wide Mediastinum And Abdominal Trauma.”) The injury itself is frequently lethal, and its time course is highly unpredictable. The delay to rupture may entail hours to days (and, rarely, weeks). The time bomb metaphor is supremely apropos.

The usual indication for diagnostic evaluation is abnormal chest x-ray results. The chest radiograph shows characteristic or suggestive findings in at least 93% of all patients with aortic injury. Unfortunately, many chest x-rays in severe trauma are necessarily acquired in supine anteroposterior fashion, and a significant number of patients without aortic injury may have a wide mediastinum on the supine view.

An upright or reverse Trendelenburg

Risk Management Pitfalls For Blunt Abdominal Trauma (Continued from page 85)

7. “The patient had a bad head injury, and we needed a head CT right away.”
Sure, there is a natural compulsion to get head-injured patients to CT. But first, the abdominal cavity must be considered. If the patient is hemodynamically unstable, DPL or US should be undertaken immediately in order to determine the likelihood of intraperitoneal bleeding. The patient in this case had no localized findings on neurologic examination; therefore, the chance of an operative lesion was extremely low. Besides, you can’t save a patient from a head injury if she dies from intraperitoneal hemorrhage first.

8. “Okay, there was a seat-belt mark, but the examination was otherwise just fine.”
A low-lying transverse abdominal ecchymosis has a strong association with hollow viscus injury. In turn, hollow viscus injury often does not produce any pain or tenderness until 6-8 hours following the traumatic event. At a bare minimum, patients with lap-belt contusions should undergo serial abdominal examinations over this time course. Findings of abdominal tenderness should prompt diagnostic study (e.g., abdominal CT) or laparotomy.

9. “It was just an isolated head injury. His pulse and blood pressure were fine, and his abdomen was not distended.”
Physical examination (including vital signs) cannot rule out abdominal injury in the comatose patient. If you wait for the abdomen to distend from blood loss, it’s time to call the coroner, not the surgeon.

10. “The orthopedist had a full schedule in the morning, and it was getting close to 2 a.m.”
Consequently, the orthopedist absconded with this multisystem injured and profoundly intoxicated patient to the OR for a washout of a matching pair of open tib-fib fractures. No abdominal studies were undertaken, and the small pneumothorax was unknown to the ortho operating team. In the OR, the combination of tension pneumothorax induced by intubation and positive-pressure ventilation plus the grade III liver injury led to a patient who was hard to bag and a pulse that was impossible to palpate. Practically any consultant, including the orthopedist in this scenario, will have blinders on. They typically see a general trauma patient from the perspective of their single discipline — in this case, a large bone. The emergency physician, together with the trauma or general surgeon, should orchestrate the resuscitation and determine the disposition.
inspiratory radiograph is helpful if the patient can tolerate this position.

Even the pristine, upright, inspiratory posterior-anterior radiograph is imperfect in predicting the presence or absence of this lesion. More accurate means of determination include helical chest CT, transesophageal echocardiography, and angiography. However, these tests take precious time.

In the relatively stable patient, there is good evidence to show that normal helical (not standard) contrast-enhanced CT of the chest results reliably excludes aortic injury.\(^1\) The unstable patient with hemoperitoneum must proceed immediately to laparotomy. The patient can undergo mediastinal evaluation with transesophageal echocardiography during the operation.\(^2\) Angiography, once the sovereign diagnostic modality in aortic injuries, is now relegated to a subordinate role in many trauma centers.\(^3\)

### Special Populations

#### Pediatrics

As with adults, motor vehicle crashes cause most of the morbidity and fatality in cases of pediatric trauma; automobile/pedestrian injuries and falls out of cars represent a large subset of these. Handlebar injuries and lap belt-only restraints are much more likely to be seen in children and can lead to pancreaticoduodenal and small bowel injury.\(^4\) Child abuse is both common and terribly harmful. Abdominal injuries are second only to head injuries as a cause of death in abused children.

A child’s abdomen has poorly developed musculature and a relatively small anteroposterior diameter. These facts amplify the vulnerability of intraperitoneal organs to compressive forces. The

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### Cost-Effective Strategies For Managing Patients With Blunt Abdominal Trauma

1. **Use your physical examination.**
   - While this article has pointed out the weaknesses of physical examination, it is certainly not without value. Patients with low-to-moderate trauma mechanism can often be managed with clinical examination alone.
   - Caveat: Patients with distracting injuries, altered sensorium, and spinal cord injuries are likely to have unreliable examinations.

2. **Avoid unnecessary laboratory studies.**
   - Mandatory testing of any kind for blunt abdominal trauma is an obsolete notion, and deservedly so. Beyond that, certain tests have very limited value (eg, serum amylase). Others add nothing to the equation. For example, in a patient with a blood pressure of 60 and a positive abdominal ultrasound, serum lactate and hepatic enzymes couldn’t be more irrelevant.
   - Caveat: Certain tests in the severely injured patient are very important. These may include a type and screen or crossmatch, as well as serial hemoglobin levels. A visual examination of the urine is important in adults, as is a dipstick or microscopic examination in children.

3. **Avoid unnecessary abdominal imaging.**
   - CT is overutilized in many institutions, and a thoughtful clinical pathway, based on the respective center’s resources, can curb some of the unnecessary enthusiasm.
   - Caveat: CT is a powerful tool in the right circumstances. It can grade organ injury and is an important modality in those with altered sensorium and suspicious abdominal examinations.

4. **Employ ED ultrasound.**
   - This wonderful tool can serve as an exceptional screening measure. From a strict cost (vs. charges) standpoint, abdominal ultrasounds are extremely cost-effective.
   - Caveat: Recognize the limitations of ED ultrasound. While it can detect 400 cc or more of intraperitoneal blood, it is insensitive to bowel and retroperitoneal injury and cannot reliably grade organ injury or routinely detect isolated subcapsular hematomas.

5. **Document, document, document!**
   - As with every aspect of medicine, adequate documentation keeps the plaintiff’s lawyer away. Make it clear that you considered the possibility of abdominal trauma, and then clarify your thought processes, diagnostic pursuit, and disposition. A thorough initial evaluation, serial examinations, and a final comparison prior to disposition are essential.
rib cage is very compliant in children, and although less prone to fractures, it provides limited protection against upper quadrant solid visceral injury. Solid organ injuries predominate in children and are responsible for 66%-90% of intraperitoneal injuries.

As in adults, most hematologic and serum chemical studies do not have adequate positive or negative predictive value to warrant their routine use. Perhaps the most valuable laboratory test for intraabdominal injury in children is urinalysis. In 1 retrospective study of 285 injured children, the physical examination combined with urinalysis showing more than 5 RBC/hpf had a sensitivity of 100% and a specificity of 64% in detecting intraabdominal injury. Microscopic hematuria portends a reasonable likelihood of injury to the liver, spleen, or kidneys. It may also be a reflection of a previously unknown coagulopathy or intraabdominal anomaly (eg, Wilms’ tumor). The threshold at which consideration should be given to further diagnostics, notably CT, varies from 20 to 50 RBC/hpf.

The important diagnostic tests used in adults with abdominal trauma (CT, US, and DPL) have somewhat different roles in children. US has been found to have comparable ability to screen for intra-peritoneal hemorrhage in adults. There has been a fair amount of controversy over the sensitivity and specificity of FAST in children, with many critics arguing that it is not reliable. However, a meta-analysis revealed a sensitivity of 80% (95% confidence interval [CI], 76%-84%) and specificity of 96% (95% CI, 95%-97%) in pediatric trauma patients. This is comparable to reported sensitivities and specificities in adult patients.

However, DPL is used differently in the injured child. It has an important role in the hypotensive child with multisystem blunt trauma in whom US is unavailable or equivocal. However, children with stable hemodynamics and hemoglobin who have blood discovered in their abdomen are much more likely to be treated without laparotomy than are adults. Therefore, DPL is generally not indicated if the child can be stabilized with blood and fluids.

CT, with its ability to discern specific organ injury both in the peritoneal and retroperitoneal spaces, remains a mainstay diagnostic test. The important caveat that applies to CT in adults applies to children as well; false-negative rates for hollow visceral and pancreatic injury are substantial: 26% and 15%, respectively.

Some authors believe that serial physical examinations are more important than CT in the diagnosis of pediatric bowel injury. In 1 retrospective study, all children with major intestinal injury had suggestive signs on presentation or shortly thereafter. These signs included seat belt ecchymoses or diffuse abdominal tenderness. The abdominal CT was insensitive in making the diagnosis and detected only 1 in 13 bowel injuries. Another study confirmed that the initial and serial physical examinations are more reliable than diagnostic testing in children with small bowel injuries.

Thirty years ago, pediatric patients with significant abdominal trauma underwent exploratory laparotomies for diagnostic evaluations. Abdominal imaging with CT has replaced that modality of diagnosis. The most common indication in children for abdominal CT after blunt trauma is hematuria. Hematuria does not necessarily imply urinary tract injury, as most children with hematuria have non-urinary tract injuries. Currently, however, a surgical procedure is usually performed only when there is a clinical indication, not based on imaging findings.

A study of 1500 consecutive children who had abdominal CT imaging following trauma revealed that only 7% underwent a surgical procedure and 75% of those decisions were based on clinical criteria. Many practitioners question the value of CT if positive findings do not necessarily lead to a surgical procedure in stable patients, especially in pediatric patients where the radiation risk is much higher.

However, 1 study reveals that CT scans lead to a change in diagnosis in 84% of patients and a 44% rate in change of treatment with 38% of those patients, constituting a decrease in monitoring and intensity of care and 6% requiring increasing care. Thus, abnormal CT scan results may not influence the decision for a surgical procedure; however, normal CT results aid in diagnostic certainty and discharge decisions. Although costly initially, it decreases the length and cost of hospital stay. These factors need to be weighed against radiation exposure in pediatric patients.

A recent article in Academic Emergency Medicine attempts to clarify the significance of a negative abdominal CT in pediatric patients following blunt trauma. Currently, many trauma centers admit pediatric patients for serial examinations even with normal abdominal CT scan results. The prospective observational cohort study enrolled 1295 pediatric patients, and 84% of them had normal abdominal CT scan results. Of the 1085 with normal scan results, 2 were later identified with intraabdominal injury: mesenteric hematoma and perinephric hematoma; however, neither underwent specific therapy.

The negative predictive value of normal abdominal CT scan results for intraabdominal injury was 99.8% (95% CI, 99.3%-100%). The article concluded that children who sustain blunt abdominal trauma with normal abdominal CT results are at very low risk of having intraabdominal injury and are very unlikely to require further intervention. Thus, hospitalization for these children is generally unnecessary and concurs with the previous paragraph that normal CT results significantly decreases cost and length of stay in the hospital.
The diagnostic approach to the elderly patient is unchanged. However, it is critical to bear 2 facts in mind. These patients are far more likely to have significant comorbid disease and to be on medications that alter their presentation, including vital signs, as well as their ability to tolerate these injuries. In addition, this group has increased morbidity and fatality for virtually any injury sustained when compared with younger cohorts. As such, management and disposition decisions should lean well toward the conservative end of the spectrum. At least 1 study suggests that an elevated base deficit (more negative than -6) during the first hour of care can help predict severe injury or death in the elderly trauma patient.

Pregnancy

Trauma is frequent during pregnancy. Women are more subject to falls after 20 weeks of gestation compared with nonpregnant patients, and the prevalence of physical abuse is 4% to 17% during pregnancy. Certain physiologic changes affect the approach to abdominal trauma. The systolic and diastolic blood pressures decline 2 to 4 mm Hg and 5 to 15 mm Hg, respectively, in the first and second trimester and then normalize in the third trimester; in addition, an increase in pulse of 10 to 15 beats per minute can be anticipated throughout. The management of shock also changes in pregnancy. The “supine hypotensive syndrome” may occur after 20 weeks’ gestation. This syndrome is caused by uterine pressure on the inferior vena cava, resulting in a drop in cardiac output of up to 28% and systolic blood pressure of 30 mm Hg. One of the first interventions by prehospital care providers and ED personnel alike is to “unload” the vena cava by pushing the uterus to the left. Alternatively, towels placed under the right side of a backboard will cause the uterus to fall to the side, accomplishing the same purpose.

The 3 primary diagnostic agents can be used throughout pregnancy, with certain precautions. US is presumed safe and accurate in this setting, but a large, prospective trial has not yet been conducted. With regard to CT, the fetus is most vulnerable to radiation while it is from 2 to 7 weeks’ gestational age.

1. **Physical Examination**
   The accuracy of the physical examination is not perfect and is rendered less so by distracting injury, head trauma, alcohol or drug intoxication, and spinal cord injury.

2. **Diagnostic Tests**
   The selection of major diagnostic studies for abdominal trauma should be based upon the clinical setting, the timely availability of the study, and the trustworthiness of that study in the respective center.

3. **Clinical Indications for Laparotomy**
   These are quite helpful in penetrating trauma. However, in blunt multi-system trauma, these are less dependable and are very uncommonly the sole reason a patient proceeds to laparotomy.

4. **The Unstable Patient**
   The critical determinant in this patient is the rapid determination of the presence or absence of hemoperitoneum. DPL is a very sensitive but invasive method of accomplishing this. Ultrasound is noninvasive and slightly less sensitive, but it can simultaneously evaluate for blood in the pericardial space.

5. **Pelvic Fracture**
   In the unstable, blunt, multi-system trauma patient with pelvic fracture, immediate ultrasound or peritoneal aspiration can determine the need for urgent laparotomy. If these studies are unequivocally negative, attention can be turned to other sources of hemorrhage, notably the pelvic vessels.

6. **Special Circumstances**
   The preferred human qualities in managing critical blunt trauma patients are common sense and quick reflexes. An algorithm can’t cover all of the permutations in the patient with some complex combination of head, chest, mediastinal, intraperitoneal, and pelvic trauma. The organ system that takes precedence is the one that is most immediately life-threatening. Then, simply do your best contending with the others until the most imminent disaster is managed.
A modified abdominal CT limited to the areas above the uterus (basically the liver and spleen) incurs a safe dosage of less than 3 rads to the fetus. Including the pelvis in the scan generates an undesirable 3 to 9 rads. However, spiral CT reduces fetal radiation exposure 14% to 30%.\textsuperscript{155} DPL is known to be accurate in pregnancy,\textsuperscript{153, 156} but should be performed by the open supraumbilical technique after the first trimester.\textsuperscript{91} Cut-off values for DPL effluent are identical to those of nonpregnant patients.

Maternal resuscitation is the prevailing tenet, and indications for abdominal laparotomy are unchanged. One disposition matter is key: Patients beyond 20 weeks’ gestation (ie, in whom the fetus is viable) who sustain torso trauma of any magnitude and who appear otherwise well should undergo at least 4 hours of fetal monitoring. This allows early detection of placental abruption, a complication of even trivial trauma.\textsuperscript{157}

**Alcoholic Patients**

*Bacchus has drowned more men than Neptune.*

—Thomas Fuller\textsuperscript{40}

Both acute and chronic alcohol usage increase the risk of abdominal trauma. From a physiologic perspective, alcoholics tend to have a lax abdominal wall and therefore incur greater morbidity from anteroposterior compressive and burst forces.\textsuperscript{158} Alcoholic hepatitis and cirrhotic liver disease lead to an enlarged liver and congested spleen, respectively. As such, these are afforded less protection by the rib cage, and their increased intracapsular pressure decreases their resistance to blunt forces. Pancreatic pseudocysts are also subject to rupture from blunt trauma.\textsuperscript{156} Finally, chronic alcoholism may result in coagulopathy with resultant exacerbated hemorrhage and complicated management.

The clinical examination and major diagnostic procedures can all be affected by acute and chronic intoxication. In a recent series, intoxicated patients were nearly 5 times more likely to have an unsuspected injury than were patients who had a negative blood alcohol level.\textsuperscript{160} If the patient’s mental status is impaired by severe intoxication or hepatic encephalopathy, the ability of the patient and the examiner to appreciate intraperitoneal and retroperitoneal manifestation is impaired.

Ascites can create difficulties in the interpretation of DPL, CT, and US. If coagulopathy is present or suspected, some authorities suggest that DPL should be performed by the semiopen or fully open technique, with careful attention to hemostasis. Portal hypertension in the chronic alcoholic can lead to engorgement of umbilical veins that pose additional hazard to the performance of DPL, particularly if percutaneous. Combativeness obviously is problematic for any of the procedures, but appropriate administration of butyrophenones should place the patient (and thus the treating emergency clinician) in a much better mood.

Severely intoxicated patients with suspected minimal trauma can be observed or committed to one or more of the diagnostic tests. This is a clinical decision that rests with the understanding of the mechanism, the clinical circumstances of the patient, and the institutional resources. For example, a very busy ED with limited personnel should move more quickly toward definitive diagnostics rather than serial observations. Finally, in patients with known intraperitoneal injury as determined particularly by CT, expectant management (ie, the deliberate observation of a patient in whom laparotomy may be unnecessary) is more hazardous than in the nonalcoholic patient.\textsuperscript{161}

**Disposition**

Three central issues face the emergency clinician: consultation, transfer, and discharge home.

**Consultation**

Consultation should be made as soon as the need is apparent. This can be based on the paramedic report from the scene or one glance at the patient being wheeled by stretcher through the doors of the ED. The purpose of consultation is, in turn, twofold.

**Need For Operation**

This is the easy one. Consultation is made as soon as there is strong suspicion or knowledge that laparotomy is necessary. The tricky part is knowing whom to call. In a trauma center, there is rarely debate, as a trauma surgeon is on call and usually in-house. At the other end of the spectrum is the community hospital that has no trauma designation and limited commitment to trauma. Here, the call should go to the general surgeon, who should respond in a timely manner. Unfortunately, the willingness and expertise (or lack thereof) of this consultant can vary. Obviously, hospital and interrelated departments need to acknowledge these scenarios and be proactive instead of simply reactive.

**Need For Evaluation**

For the obviously and seriously injured trauma patient, an immediate consult with the trauma or general surgeon allows the team to evaluate, then expedite, care. It is right for the emergency clinician, the surgeon, and the patient.

The approach to the relatively stable patient varies among and within hospitals. Optimally, the emergency medicine, surgical, subsurgical, and radiology groups will have convened and agreed on diagnostic and management algorithms. Otherwise, the number of permutations in management is enormous.
Admission practices vary widely among hospitals. Many authorities favor admitting multiple trauma patients with, for example, orthopedic concerns to the trauma or general surgeon with consultation by the orthopedist and not vice versa at least for the first 24 to 48 hours of care. This basic principle applies to the pregnant, pediatric, and geriatric patients as well. However, no prospective studies have evaluated this approach.

Transfer
The patient must be transferred if the base hospital is incapable of providing adequate care. The missing ingredient(s) may include a diagnostic test OR surgical staff, surgeon, monitored bed, or specialist. Once it becomes clear that transfer is needed, delay in transfer should be strictly avoided. In general, diagnostic studies — particularly those that are time consuming — should be undertaken at the receiving hospital, unless that test is integral to determining the need for transfer in the first place.

The transfer itself should abide by EMTALA regulations. The mode of transfer and the type of personnel involved rest with the patient’s clinical status, available resources, weather conditions, traffic patterns, and the like.

One thorny issue that may arise in smaller hospitals relates to the hypotensive patient with probable intraabdominal bleeding. Such patients may not survive the transfer to a higher level of care. For such patients, it is useful to consult the local surgeon regarding the possibility of “damage control” laparotomy. In such a case, the local surgeon would perform an emergent laparotomy with the sole purpose of staunching life-threatening hemorrhage. When the bleeding is controlled, the patient may then be transferred (even with an open abdomen with packs in place) to the trauma center.162, 163

If a damage control surgical procedure is an option, then the emergency clinician may elect to perform a DPL or US on such unstable blunt trauma patients early in the course of evaluation.

Discharge Home
Certain patients — notably, those with single-system trauma and stable vital signs — can be discharged home after a period of observation with or without US, DPL, CT, or some combination thereof. These patients can be sent home only if their mental status, vital signs, and host status (immune, coagulation) are at or close to baseline and their social support systems competent. The emergency clinician must be very cautious for those at increased risk for delayed presentation or worsening, such as the patient with mechanism (eg, spearing, as with a handlebar injury) or clinical features (eg, seat belt mark) consistent with hollow viscus injury. In these situations or for patients with persistent abdominal tenderness following serial observation, it is far wiser to consult the trauma surgeon and proceed with further observation or studies.

For patients with a CT with negative results, conservative pundits argue that 12 to 24 hours of in-hospital observation is mandatory. This is to enable discovery of late presenting injury, particularly bowel disruption missed by CT, as well as allow the opportunity for CT to be read by the institution’s expert the following morning. However, 1 recent observational study of 2299 blunt trauma patients demonstrated that normal abdominal CT scan results ruled out significant injury in 99.63% of patients. In this series, there were only 6 therapeutic laparotomies in patients with initially normal CT scan results (intestine in 3, bladder in 1, kidney in 1, and diaphragm in 1). The authors concluded that most patients with a CT scan with negative results after suspected blunt abdominal trauma do not require either hospital admission or prolonged observation.24

The approach to discharging a patient with normal abdominal CT results and no other significant injuries is best individualized according to the center and the patient. Consider the resources available to the patient and his or her ability to recognize clinical worsening and then return should it occur.

Summary
The recipe for successful abdominal trauma management calls for just a few main ingredients. First, the prospect of the existence of abdominal injury must be considered. When that suspicion has arisen, appropriate diagnostic studies, clinical observation, or both should identify those with abdominal injury in reasonably short order. For injuries that may be missed because of insensitivity of the physical examination and inaccuracy of the diagnostic study, further observation or testing is warranted. Patients whose medical needs cannot be met should be delivered to regional centers for care as quickly as possible. Finally, close cooperation with trauma-related services and administrators encourages good outcomes and efficient resource use.

References
Evidence-based medicine requires a critical appraisal of the literature based on study methodology and number of participants. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, is included in bold type following the
reference, where available. In addition, the most informative references cited in the chapter, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.


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CME Questions

33. In patients with known pelvic fracture, DPL should be performed by which one of the following?
   a. Seldinger technique infraumbilically
   b. Seldinger technique supraumbilically
   c. Fully open technique infraumbilically
   d. Fully open technique supraumbilically

34. A multiple blunt trauma patient has blood pressure of 70, severe closed head injury (GCS 6, nonlocalizing neurologic examination), an AP pelvis radiograph with negative results, and greater than 10 cc gross blood by DPL. He is most likely to have:
   a. An epidural hematoma
   b. An intraventricular bleed
   c. A grade III liver laceration
   d. Significant retroperitoneal hemorrhage

35. The “spearing” mechanism to the mid-abdomen is likely to result in:
   a. Splenic fracture
   b. Retroperitoneal hematoma
   c. Perforated ileum
   d. Myocardial contusion

36. The PASG has been proven to:
   a. Diminish fatality in penetrating trauma patients
   b. Diminish fatality in blunt trauma patients
   c. Decrease systemic vascular resistance
   d. Decrease retroperitoneal hemorrhage in certain pelvic fractures

37. A motor vehicle crash survivor presents to the ED with a blood pressure of 118/70, pulse of 92, upper chest abrasions, and bilateral open tibia-fibula fractures. He smells of alcohol but is clinically sober. Under what circumstances should the patient undergo US before going to the OR for washout of the fractures?
   a. No matter what
   b. If the abdomen is tender to examination
   c. Only if the hemoglobin is less than 12 gm/dL
   d. Only if the serum ETOH is greater than 100 mg/dL

38. CT has less sensitivity for the detection of which pair of the following?
   a. Large bowel, liver
   b. Small bowel, pancreas
   c. Kidney, pancreas
   d. Kidney, liver

39. A pedestrian struck by a car presents with a blood pressure of 60, pulse of 124, 400 cc in a right chest tube, and a right femur fracture. Because of hypotension, he should next undergo which one of the following?
   a. Abdominal laparotomy
   b. Abdominal CT
   c. DPL
   d. Serial abdominal examinations
40. A patient falls out of a 2-story window, lands on his buttocks, and sustains a pelvic fracture. His blood pressure at the scene is 100 mm Hg, and in the ED after 500 cc normal saline, it is 120 with a pulse of 100. The aspiration portion of DPL is negative, but the RBC count of the recovered effluent is 100,000 RBC/hpf. He should now undergo:
   a. Abdominal laparotomy
   b. Abdominal US
   c. Abdominal CT
   d. Pelvic angiography

41. A pedestrian struck by a car presents with blood pressure of 80, pulse of 110, a moderately wide mediastinum without hemothorax on an anteroposterior radiograph, and a positively resulting FAST for intraperitoneal fluid. The next step for this patient should be:
   a. Posterior-anterior upright chest radiograph
   b. Abdominal CT
   c. Thoracotomy
   d. Laparotomy

42. Regarding diagnostic studies in pediatric blunt abdominal trauma patients, which one of the following is false?
   a. US has the excellent ability to determine the presence of hemoperitoneum.
   b. CT is the procedure of choice for nonoperative management.
   c. DPL is useful in hemodynamically unstable patients.
   d. Serum amylase and liver function tests are effective screens for intraabdominal injury.

43. Which of the following should be absolutely avoided in the blunt trauma patient who is in the third trimester of pregnancy?
   a. Abdominal US
   b. Infraumbilical Seldinger technique DPL
   c. Upper abdominal CT
   d. Abdominal helical CT

44. A 26-week pregnant 21-year-old presents after falling down 3 steps. Her examination results are entirely normal, including US results, which demonstrate a fetal heart rate of 130 and no intraperitoneal fluid. The correct disposition for her is:
   a. Helical abdominal CT
   b. Fetal monitoring for 4 hours
   c. Fetal monitoring every 24 hours
   d. Discharge home

45. Which of the following is true regarding isolated small bowel injury?
   a. Clinical signs are often delayed by more than 6 hours.
   b. DPL red cell threshold of 100,000 is usually exceeded.
   c. US has grossly positive results.
   d. Plain radiograph always demonstrates free air.

46. A 10-year-old child presents with abdominal pain after being tackled in a football game. His examination, including vital signs, is unremarkable. His hemoglobin is 13.4 and UA reveals 50 RBC/hpf. He should now receive:
   a. Intravenous pyelogram
   b. Abdominal CT
   c. Abdominal US
   d. Follow-up with his pediatrician

47. What measure of pulse change (beats per minute) can be expected throughout pregnancy?
   a. Increase of 10 to 15
   b. Increase of 20 to 30
   c. Decrease of 10 to 15
   d. Decrease of 20 to 30

48. When compared with the healthy patient, which of the following regarding the chronic alcoholic blunt abdominal patient is true?
   a. Intraperitoneal solid organ injury is less likely following compressive forces.
   b. Intraperitoneal hollow viscus injury is less likely following “spearing” mechanism.
   c. Expectant management of known intraperitoneal injury is more successful.
   d. Fatality is greater for comparable levels of intraperitoneal injury.
March 15, 2000: A 20-year-old woman presents to the ED after falling while she was rollerblading. She has a swollen wrist, but no tenderness in the snuffbox. Her films are normal. She is discharged with instructions to return if she has any problems.

August 12, 2001: You receive an operative report from a local orthopedist. He has copied you on a procedure note regarding a 21-year-old woman with a condition you’ve never heard of—“Kienbock’s disease.” You wonder, “What does this have to do with me?”

Although wrist injuries are common, they can hardly be described as routine. True, most of us can identify a radius fracture when we see one, and we can usually recognize a carpal fracture. We also know that navicular tenderness suggests an occult fracture, which requires follow-up with an orthopedist.

However, wrist injuries are often quite complex. They comprise a continuum of bony, muscle, and ligamentous damage. Physical examination and radiographic findings are rarely conclusive. Moreover, both recognized and occult injuries can lead to significant long-term sequelae. Because patients rely on their hands for careers and day-to-day activities of all kinds, complete recoveries are usually a must. It is little wonder that wrist injuries (especially with missed or delayed diagnoses as well as inadequate treatment) are common causes of malpractice suits against emergency clinicians.

The literature on wrist injuries can be confusing. The emergency literature is sparse, and studies in the orthopedic, hand, and radiologic journals focus on retrospective, operative, and often theoretic concerns. Short of splinting everything, the emergency clinician is often left without a comprehensive guide for the evaluation and management of wrist injuries. This chapter aims to fill this void by describing the state of the art emergency department (ED) management of wrist injuries.

State Of The Literature

Much of the management of wrist injuries is based on anecdote, tradition, and local practice. There are few prospective, randomized trials to support the different emergency treatment strategies. Moreover, given the nature of wrist injuries, this is unlikely to change. Imagine trying to convince the hospital’s institutional review board to randomize ulnar dislocations to either next-day reduction or treatment in the ED. It would be no easier to persuade multiple centers to standardize treatments and enroll patients for once-a-year occurrences such as perilunate dislocations. Therefore, we as emergency clinicians are largely left with small retrospective series and “common sense.” Common sense, however, does not lend itself to the rigorous methodology that is the foundation of evidence-based medicine. As one writer mused, “Common sense is part of the home-made ideology of those who have been deprived of fundamental learning, of those who have been kept ignorant.”

Epidemiology

Injuries to the wrist account for about 2.5% of orthopedic injuries seen in the average community ED. In 1 study, the incidence of wrist injuries that prompted radiography was 26 per 10,000 per year.
In more practical terms, the average emergency clinician sees wrist injuries at least several times each month, if not every day or week.

Most wrist injuries (90%) are the result of a fall on an outstretched hand. Although the characteristics of wrist injuries vary with age, no age group is spared. Children fall at play; the elderly fall in their homes. A recent study also suggests that wrist fractures in the elderly may be strongly associated with falls due to vestibular dysfunction.\(^5\)

Although falls are the predominant cause of wrist injuries among patients of all ages, the type and outcomes of the injuries sustained do vary by age. Young children almost never have carpal fractures but may sustain distal radial fractures (especially torus [bulging of the cortex] and greenstick fractures). A fall on an outstretched hand in a toddler or young child may also result in a radial head or supercondylar humerus fracture. Adolescents and young adults are more likely to injure the carpal bones, especially the scaphoid. When they do sustain a distal radius fracture, it is often complex and associated with other injuries. With increasing patient age, scaphoid fractures become less common, whereas distal radius fractures become more so.

In addition, adults are more involved in the kinds of sports and recreation activities that put them at higher risk for wrist injuries. This accounts for a rise in high-velocity injuries associated with bicycling, skating, and other outdoor sports seen in suburban EDs. Emergency clinicians in urban areas may also see crush injuries due to industrial injuries.

Pathophysiology: Anatomy And Biomechanics

The wrist joint allows a range of motion from about 75° of volar flexion to 70° of dorsal extension, with about 45° of ulnar and radial deviation and 180° of rotation. This mobility, in combination with the extrinsic flexors and extensors, permits remarkable dexterity.

The wrist includes all of the bones and articulations from the distal radius and ulna to the carpo-metacarpal joint. This includes the bases of the 5 metacarpals, 8 carpal bones arranged in 2 rows, and the distal 4 to 5 cm of the radius and ulna. As you read this section, palpate your own anatomy and identify the important landmarks.

Bones

The carpals are arranged in 2 semiparallel arches. From radius to ulna the proximal arch includes the scaphoid, lunate, triquetrum, and pisiform. The distal row (radius to ulna) includes the trapezium, trapezoid, capitale, and hamate. The trapezium and trapezoid are also known as the greater and lesser multangulars. Because the distal carpals are intimately connected to the metacarpals, they are more stable and less frequently injured.

Articulations

The proximal row of carpals sits in the concavity formed by the triangular fibrocartilaginous complex (TFC) and the radial styloid. The articulation between the 2 rows of carpals is called the midcarpal joint, and the scaphoid bridges and stabilizes the 2 rows.

The radius articulates with the lunate, scaphoid, and ulna. The ulna has no direct connection with the carpals, but it is joined to the triquetrum by the TFC. Articulation between the radius and ulna is through the TFC and the sigmoid notch on the ulnar surface of the distal radius, which allows rotation of the forearm. Because the TFC forms the ulnar border of the wrist, it is important to the wrist’s stability.

Muscles

Most of the muscles that move the wrist attach to the metacarpals, allowing the carpals to move passively. The flexor carpi ulnaris is the only muscle that connects to the carpal bones (the pisiform). About 60% of flexion and radioulnar deviation occurs at the midcarpal joint, 60% of extension occurs at the radiocarpal joint, and rotation occurs mostly at the radioulnar joint.\(^6\)

Ligaments

Although the bones are easily discernible on x-ray, it is the ligamentous elements that stabilize the wrist. They dictate much of the injury pattern and account for many missed wrist injuries. The ligamentous support of the wrist consists of the extrinsic ligaments (which bind carpal to forearm) and intrinsic (which bind carpal to carpal). There are many named ligaments making up these groupings, but to the nonoperative emergency clinician, the overall function is best conceptualized in groups. The individual extrinsic ligaments essentially form a single dorsal and 2 volar arcades.

The volar arcades approximate 2 “V”-shaped arches starting at the radial styloid, reaching the carpals distally, and returning toward the ulnar styloid, attaching at the TFC. The proximal ligamentous arch reaches the lunate in the proximal row of carpals; the distal ligamentous arch reaches to the capitale. Between these 2 arches is an un-reinforced area of the joint capsule called the space of Poirier, at the approximate level of the lunocapitate junction. With forceful extension, this space can widen and tear; failure of ligamentous integrity can lead to instability or dislocation between the carpal rows.\(^7\) Because the extrinsic ligaments attach at the styloid, their integrity is crucial to the stability of the wrist.

Believe those who are seeking the truth.
Doubt those who find it.
—André Gide
ED Evaluation

Serious or life-threatening injuries take precedence during any patient encounter in the ED. With the exception of an uncontrolled arterial bleed, acute wrist injuries by themselves are never a life threat. However, do not be lulled by a primary complaint of wrist pain before evaluating the patient. That wrist complaint may simply be the most painful of the injuries caused by a high fall; likewise, it could be a marker of cardiac syncope in an elderly patient.

History

Important historical considerations include when and how the injury occurred. Remember that cuts and even superficial abrasions (“hesitation cuts”) to the volar wrist may be evidence of a suicide attempt; at least 7% of suicidal adolescents present with wrist lacerations. Understanding how the various mechanisms influence wrist injury will help direct both the physical examination and evaluation of radiographs.

As mentioned, 90% of traumatic wrist injuries result from a fall on the outstretched hand, giving us the onomatopoeic acronym “FOOSH.” FOOSH injuries comprise the most frequent and well-recognized trauma to the wrist—fractures of the distal radius and scaphoid. This same mechanism can also break bones located on the palmar surface of the hand by direct impact (ie, the hamate and pisiform) and can lead to significant ligamentous injuries. A fall on an outstretched hand may cause more proximal injury as well, often to the elbow or even shoulder.

Direct trauma to the wrist usually breaks the more exposed bones, such as the styloids and triquetrum or metacarpals. The carpals, especially the hamate, may be injured if someone wielding a stick (eg, golf club, baseball bat, or nightstick) hits an unyielding object (eg, ground, fastball, or skull). Extension or rotational injuries can lead to dislocations, such as ulnar dislocation. Injuries outside the FOOSH mechanism typically do not cause scaphoid fracture or Colles’-type radius fractures.

Punctures, foreign bodies, amputations, punch injuries, and crush (roller) injuries probably cause more disabilities than fractures. If the injury is open, determine what contaminants are possible, such as water, soil, or foreign bodies. In such patients, tetanus status is an important concern.

In patients with severe injuries, pain in the wrist is the predominant symptom. When patients present days to weeks after injury, they may have other complaints. Patients with ligamentous injury may note a “clunk” or snapping sensation with movement of the wrist and frequently report loss of hand strength.

Ask about preexisting medical conditions such as rheumatoid arthritis as well as previous injuries, because these may alter the baseline function and radiographic appearance of the wrist. If an emergent surgical procedure is anticipated, determine the time of the patient’s last meal. Standard questions regarding allergies and current medications may be helpful if analgesics, antibiotics, or other medications are anticipated.

Physical Examination

Once the ABCs have been addressed, evaluation of any orthopedic injury starts with confirmation of neurovascular integrity. Both the ulna and radial arteries are readily available to examination. In addition to the usual volar location, the radial pulse can often be palpated in the snuffbox as well. In most people, patency of either one of these vessels is sufficient to perfuse the hand. Capillary refill at the fingertips will confirm the distal circulation.

The Allen test may be helpful in patients with suspected arterial injury. To perform this test, the patient should be supine with his or her hand in the air. Then have the patient repeatedly pump his or her fist. Instruct the patient to clench his or her fist tightly for several minutes while applying firm pressure to both the ulnar and radial arteries. Initially release the radial artery and determine how long it takes for the blanched hand to return to its normal color. Repeat this test, this time releasing the ulnar artery while maintaining pressure on the radial artery. Use the opposite hand as a control. A significant delay in refill time requires emergent consultation with a surgical specialist. Remember that patients with arterial injuries will likely have nerve damage as well because of the proximity of these structures.

Neurologic integrity of the hand is best confirmed with 2-point discrimination. Most people can detect 2 points at 0.5 cm apart on the finger pads. Splitting a tongue blade with a twisting motion provides 2 sharp points that can be placed in the longitudinal axis of the fingertip border (so as not to cross between nerve fields). Motor testing becomes difficult with pain, but gross function should be confirmed. Test all 3 major nerves. To test ulnar nerve motor function, ask the patient to abduct his or her fingers (spread them apart against resistance). This will challenge the first dorsal interossei, which are supplied by the ulnar nerve. The sensory branch supplies the volar aspects of the fifth finger and the radial and the ulnar half of the fourth finger.

To test the median nerve, have the patient lay his or her hand flat with the palm up and then lift the thumb straight up from the palm. Press against the thumb to determine appropriate resistance (the median nerve innervates the abductor pollicis brevis). The sensory function of the median nerve is best tested at the distal pulp of the index finger. The radial nerve supplies the motor function to wrist and finger extension via the extensor muscles of the forearm but does not innervate the intrinsic muscles of the hand; therefore, a motor deficit of the...
radial nerve is unlikely in an isolated wrist injury. To test the motor branch of the radial nerve, have the patient extend the thumb or wrist against gravity. The sensory innervation of the radial nerve is best examined in the first dorsal web space (between the thumb and index finger).12

Suspicion of a particular injury should prompt targeted assessment of the jeopardized nerve. For instance, when a hamate injury is suspected (classic mechanism or tenderness over the base of the hypothenar eminence), closely examine the motor and sensory function of the ulnar nerve. This nerve passes close to the hook of the hamate and can be crushed during trauma to the hamate. When a Colles’ fracture is likely, perform a detailed assessment of the median nerve. This nerve may be damaged by either direct injury from a fracture fragment or by stretching.

Stated a different way and perhaps more obvious to the practitioner, neurologic symptoms such as paresthesias or weakness should offer clues that something is amiss after a traumatic incident. No one should be discharged from the ED complaining of numbness or neurological deficits without appropriate imaging or consultation. Paresthesias within the median nerve distribution suggest lunate dislocation into the carpal tunnel. Carpal tunnel syndrome differs from a lunate dislocation in that the onset of symptoms would be gradual and have nocturnal exacerbations. Ulnar paresthesias or inability to abduct one’s fingers suggest a fractured pisiform or hamate compromising Guyon’s canal.15

Look for any break in the skin in association with an orthopedic injury, as this may represent an open fracture. In addition, depending on the mechanism, a search for foreign bodies may be warranted. In addition to examining for injury to the hand, manipulation of the fingers and metacarpals can provide clues to carpal injury. Look at the stance of the resting hand. Are all of the fingers in a normal cascade (index and thumb the least flexed position, progressing to greater flexion in the third, fourth, and fifth digits)? An extended finger usually signifies a flexor tendon injury, whereas abnormal flexion identifies an extensor tendon defect.

Next, examine the range of motion of each finger and test the tendon strength against resistance. Test the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) separately. Test the FDP by having the patient flex the distal interphalangeal joint of each finger. To test the FDS of an individual digit, hold all of the other fingers in full extension at the distal joint while asking the patient to flex the proximal interphalangeal (PIP) joint of the finger in question. It is important to test both the FDP and the FDS, because patients with a complete laceration of the superficial tendon may still be able to flex the finger by using the FDP.14

In the patient with blunt wrist trauma, push each finger directly into the hand. By applying axial force on the fingers (and thus the associated metacarpals), the carpal bones are stressed. For example, axial loading of the third digit will elicit pain in capitate or lunate fractures. Pain increased by axial loading of fourth and fifth metacarpals is frequent with hamate injury. Flexion of these fingers will also cause pain in the hypothenar eminence in those with a fracture of the hook of the hamate.

A meticulous wrist examination is, of course, crucial. Occasionally, tenderness and swelling will limit the examination, but time devoted to careful examination is likely to be fruitful. Physical examination is the best guide to which (if any) radiographs are necessary. Order additional radiographs based on your examination to focus on the suspected injury. Snuffbox tenderness mandates different radiographic views than tenderness of the ulnar styloid or the hamate.

The skin and connective tissue around the wrist is generally mobile and devoid of fatty deposit. The bones of the wrist are small but close to the surface. Most of the carpal bones are palpable—try to feel each one to determine the point of maximal tenderness. Remember key aspects of the surface anatomy of the wrist. Important landmarks include the anatomical snuffbox on the radial border of the wrist, the scaphoid tubercle (palpable below the thenar eminence), the pisiform (felt below the ulnar border of the hypothenar eminence), and the radial and ulnar styloids.

The proximal extent of the wrist is marked by the radial and ulnar styloids. The anatomic snuffbox is defined proximally by the radial styloid, dorsally by the extensor pollicis longus tendon, and volarly by the extensor pollicis brevis and the abductor pollicis longus tendons (the ideal location for snorting stuff). The scaphoid (navicular in the older literature) is palpated in the floor of the snuffbox.

Lister’s tubercle is the prominence on the dorsal aspect of the distal edge of the radius, just radial to the middle of the wrist. Rolling distally, just over the tubercle, and slightly ulnar, with the wrist in neutral position, there is a small depression. This depression marks the space between the radius and the capitae and the scapholunate joint. As the wrist is flexed, the lunate is palpable as it rises out of this depression. This is one of the easiest places to palpate a wrist effusion, traumatic or otherwise. (This is also the best place to tap a wrist.) Moving toward the ulna just distal to the ulnar styloid is the TFC; distal to that is the triquetrum.

On the volar side of the wrist, the scaphoid tubercle is palpable just distal to the palmar margin of the radial styloid, at the base of the thenar eminence. Across the wrist crease, at the base of the hypothenar eminence, is the pisiform. Just distal and radial to this, the hook of the hamate is palpable in the meat of the hypothenar eminence. The volar wrist crease marks the base of the proximal row of carpals.

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Because of its ubiquity and high complication rate when missed, a diligent search for signs of scaphoid injury is useful. Snuffbox tenderness is the most familiar sign, but tenderness of the scaphoid tubercle is also an important finding. Supination of the forearm against resistance exerts shear forces across the scaphoid, and pain with this maneuver suggests fracture. To perform this test, ask the patient to “shake hands” with you and tell the patient not to let you twist her or his wrist. In the presence of a scaphoid injury, the patient will complain of pain in the snuffbox when you try to twist her or his rigid hand. An alternative test involves axial loading of the thumb. By pushing directly down the axis of an extended thumb, pressure is applied directly to the scaphoid.

Waeckerle examined these 3 signs in 85 patients (with 40 fractures identified acutely or on follow-up) and found snuffbox tenderness had a sensitivity of 100% and a specificity of 98% for ultimate detection of fracture (either on immediate radiography or at 2-week follow-up). Supination against resistance had a sensitivity of 100% and a specificity of 98%. Longitudinal compression of the thumb had a sensitivity of 98% and a specificity of 98%. In a separate prospective study, other authors evaluated 4 clinical signs believed to be useful in the diagnosis of scaphoid fracture. They examined 215 consecutive patients with suspected scaphoid fracture on 2 separate occasions for the following clinical variables: tenderness in the anatomical snuffbox; tenderness over the scaphoid tubercle; pain on longitudinal compression of the thumb; and the range of thumb movement. At the initial examination, tenderness in the snuffbox, tenderness over the scaphoid tubercle, and longitudinal compression of the thumb were all 100% sensitive for detecting scaphoid fracture. However, their specificities were dramatically lower than those in Waeckerle’s study, with specificities of only 9% for snuffbox tenderness, 30% for tubercle tenderness, and 48% for pain with axial compression of the thumb.

Abnormalities in the range of thumb movement had 69% sensitivity and 66% specificity. However, the authors found that the combination of snuffbox and tubercle tenderness along with pain on compression of the thumb was 100% sensitive and 74% specific within the first 24 hours following injury. Unfortunately, this algorithm has never been revalidated. Note also that in this study, 6 of the 56 scaphoid fractures were reported as nontender in the snuffbox at the 24-hour follow-up.

Importantly, the article just referenced reports that the 9% specificity of snuffbox tenderness for scaphoid fractures leads to overtreatment of 85% of patients with acute wrist injuries. Overtreatment involves unnecessary immobilization of the joint, missed financial and recreational opportunities, and needless health care expenses. Many emergency clinicians face a difficult management dilemma when they are forced to decide whether to immobilize a patient with scaphoid tenderness and a negative plain radiograph, risking unnecessary immobilization and costs or the chance of the rare possibility of avascular necrosis. This debate is the most controversial issue currently affecting patients with wrist injuries. Although this will be more thoroughly discussed later, the best management is to splint these patients in a removable, less-inhibiting splint with early orthopedic follow-up for patients with persistent pain or to CT these patients to obtain diagnostic certainty.

Although most injuries occur on the radial side of the wrist, do not neglect the ulnar aspect during the examination. The ulna can displace dorsally or volarly. Pain and deformity in the area of the ulnar styloid are the hallmarks of a radial ulnar dislocation, but this finding is difficult to interpret when associated with other wrist injuries. With disruption of the radioulnar joint, rotation of the forearm will be exquisitely painful.

A final caveat: When examining the wrists, always take advantage of the fact that the wrist is a paired structure. To detect subtle findings, have the patient hold both arms out together and compare both sides.

You can observe a lot by just watching.
—Yogi Berra

**Radiology**

The Ottawa rules provide an excellent guide to determine when to order ankle radiographs. However, the anatomy of the wrist is more complex, with a wider range of injuries, and radiographs harbor more subtle findings. There have been attempts to develop an algorithm that defines criteria for radiography in the injured wrist or extremity among children, but none has been validated or is powerful enough to influence clinical practice. In fact, the authors of one orthopedic text summarize current practice by stating, “With rare exceptions…imaging is an absolute requirement in the diagnosis of injury or disease involving the wrist.”

Algorithms and recommendations for imaging in wrist trauma come from the orthopedic and hand literature, and many are impractical for the emergency clinician. They start with x-rays, move to special views, and get progressively more expensive (magnetic resonance imaging [MRI], bone scan, or computerized tomography [CT]) or invasive (arthrogram and arthroscopy). Several studies in the emergency literature examine x-ray strategies for specific wrist injuries, but they are predicated on determining the specific wrist injury in question before obtaining the imaging studies. It should be
An Evidence-Based Approach To Traumatic Emergencies

Stressed that the literature about missed injuries is far more abundant than guidelines attempting to curtail x-ray use.\textsuperscript{25-30} In general, any patient with wrist trauma who has point tenderness of the wrist or a test suggesting a scaphoid injury should have an x-ray. Beyond this, the literature on who needs a radiograph is silent.

Wrist radiographs can be intimidating. The 14 bones have subtle relationships that change with wrist positioning. Therefore, it is essential to have a system or mental checklist to evaluate wrist radiographs.\textsuperscript{(See Table 1.)}\textsuperscript{31} First, assess the adequacy of the radiograph, then look at the alignment and angles of the bones, and, finally, note the bone shape.

Adequacy Of Radiographs

The standard wrist series includes both a posterior-anterior (PA) and lateral view. Although controversial, some hospitals routinely include an oblique view. In 1 prospective study that examined the utility of oblique views in extremity trauma in 1461 patients, the addition of the oblique view changed the interpretation in 70 (4.8%) examinations as well as increasing diagnostic confidence.\textsuperscript{32} Radiographs should include the carpometacarpal joint to the distal 5 to 6 cm of the radius. When taking the radiograph, the patient’s elbow should rest on the x-ray table in 90° flexion, with the shoulder in 90° abduction. The beam is centered on the carpals. For this reason, hand radiographs, although they include the carpals, are inadequate for wrist assessment. Deviation or rotation of the hand will alter the appearance and alignment of the carpals and their relation to the ulna and radius. Therefore, the emergency clinician should first assess the positioning of the hand on radiographs using the following guidelines.

<table>
<thead>
<tr>
<th>Table 1. Systematic Assessment Of The Wrist Radiograph</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adequacy:</strong></td>
</tr>
<tr>
<td>- Carpal-metacarpal junction to distal 5 cm of radius is included.</td>
</tr>
<tr>
<td>- Hand is neutral in both the PA and lateral views. The axis of the middle metacarpal lines up with the middle of the radius.</td>
</tr>
<tr>
<td>- Rotation (PA view): There is a gap between the two bones at the radioulnar joint. The ulnar styloid projects laterally.</td>
</tr>
<tr>
<td>- Rotation (lateral view): The radius and ulna are superimposed or within 3 mm dorsally. The pisiform should overlie the head to the scaphoid.</td>
</tr>
</tbody>
</table>

| **Alignment and angles:** |
| - The three smooth articulating cortical lines of the carpals are visible. |
| - There is no more than 2-3 mm between individual carpals. |
| - The radius articulates with at least half the lunate. |
| - Radial inclination is 16-28° on PA view. |
| - Radial volar (or palmar) tilt is 0-22° on lateral view. |
| - Scapholunate angle is < 65° on lateral view. |
| - The radial length is 11-12 mm. |

| **Bony shape:** |
| - The scaphoid shows a cortical ring when dislocated on the PA view. |
| - The lunate should be quadrangular on PA view; triangular shape implies rotation or displacement. |
| - The pisiform is the last carpal to ossify up to age 12 years. |

| **Special views:** |
| - Scaphoid: Views the long axis of the scaphoid. |
| - Carpal tunnel: Views the pisiform and hamate. |
| - Semi-pronated: Views the radial elements (trapezium and scaphoid tuberosity). |
| - Semi-supinated: Views the ulnar elements (pisiform and hamate). |

PA View

The hand should be in neutral position with the axis of the middle metacarpal lining up with the axis of the radius. Although the distal radius and ulna should not touch at the radioulnar joint, the gap should be less than 2 mm. The ulnar styloid should project laterally from the end of the ulna in a true PA. Superimposition of the styloid on the ulna suggests rotation or improper positioning.\textsuperscript{33,34}

Lateral View

On the lateral view, the axis of the middle metacarpal should continue through the capitate, lunate, and radius. The dorsal surface of the ulna should be overlying, or less than 3 mm posterior to the dorsal surface of the radius. The 4 ulnar metacarpals should overlap one another (see Figures 1 and 2), and the pisiform should overlie the head of the scaphoid.

Alignment And Angles

On the PA view of a normal wrist, the radius and ulna are the same length at the radioulnar joint. The radial styloid projects 11 to 12 mm farther—a distance known as “radial length.” There is a “radial inclination” (the slope of the radius from the styloid down to the radioulnar joint) of 16° to 28°.\textsuperscript{35} The carpals should line up as arches, with up to 2 mm between the individual carpals and between the 2 rows. Three smooth radiographic arcs should be recognizable.\textsuperscript{(See Figure 3, page 106.)} The first follows the proximal cortices of the scaphoid, lunate, and triquetrum; the second outlines the distal surfaces of this proximal carpal row; and the third outlines the proximal surfaces of the capitate and hamate.\textsuperscript{36}

On the lateral view of the normal wrist, the radius has a “volar tilt” of 9° to 13° and the scaphoid...
should be palmar flexed, with a normal scapholunate angle of 30° to 60° from the axis of the carpals.

**Bony Shape**

In addition to fracture lines and displacement, the shape of the carpal bones provides valuable clues to injury. On the PA projection, the scaphoid length is seen, and it will gently cup the capitale. If it rotates, as in some dislocations, it will be foreshortened, and the cortex of the distal pole will superimpose over the body, projecting the illusion of a “signet ring.” The properly aligned lunate will be generally trapezoidal on the PA view. As it rotates volarily, as in dislocations, it will look more like a triangle. (See Figures 4 and 5, page 106.)

**Special Views**

Special views are generally ordered when a specific injury is suspected. In the pronated oblique view, the radial palm is lifted 45°, leaving the ulnar palm on the cassette. This view offers a better view of the trapezium and scaphoid tuberosity as well as the bases of the first 2 metacarpals. The scaphoid view, or ulnar-deviated PA, is shot with the palm flat and in ulnar deviation. It projects the length of the scaphoid better than the routine views. (See Figure 6, page 107.) The supination oblique view is an anterior-posterior (AP) rather than PA view. It is shot with the radial side lifted 45° and the ulnar side of the dorsum of the hand on the cassette. This gives better exposure to the pisiform and hamate. (See Figures 7 and 8, page 107.) The carpal tunnel view is shot through the carpal tunnel with the wrist maximally extended. It provides a look at the bones forming the tunnel, mainly the hamate and pisiform.

The literature is rife with reports trumpeting the limitations of plain radiography in wrist injury. But do we have an imaging alternative? One interesting study compared plain radiographs and MRI in 67 patients with severe wrist trauma. Three radiologists evaluated both the standard x-rays and magnetic resonance (MR) images in a blinded fashion in all patients. One-third of the 37 fractures (n = 13) observed on MR images were missed on the radiographs. The authors recommended that MRI be considered in severe wrist trauma when “1) There is a clear discrepancy between the clinical status and a negative radiography and when splint treatment would increase cost by causing occupational restrictions; and 2) Healing of trauma diagnosed as contusion or distension does not occur within the expected time.” However, the cost, implications, and utility of this recommendation have not been prospectively examined.

Because the wrist in the most commonly injured joint and fractures are often subtle on plain

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**Figure 1. PA View Of The Wrist**

![Image](image1.png)

**Figure 2. Lateral View Of The Wrist**

![Image](image2.png)

*Reproduced with permission from: Harris JH, Harris WH, eds. The Radiology of Emergency Medicine. 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:377. Fig. 6.2B.*
radiographs, leading to missed diagnoses in the ED, further radiological aid should be used to avoid missing injuries and the resulting chronic pain and disability. Having a 9.3% misinterpretation rate on plain radiograph radiography, wrists are 1 of the 4 most common radiological errors and 1 of the 3 most common errors of clinical importance.

A recent study out of South Korea examined the added benefit that a CT of the carpal bones would add to plain radiography in diagnosing wrist injuries. Patients with wrist injuries underwent routine plain radiography including wrist AP, lateral and wrist and hand oblique radiographs, and hand PA and oblique views. If certain fractures were suspected, additional views were obtained such as ulnar-deviated PA view for a potential scaphoid fracture or a supination oblique view for a possible pisiform or hook of the hamate fracture.

When a fracture was not seen on the plain radiographs but was suspected clinically or when additional fractures were suspected, a wrist or carpal CT was performed. The sensitivity and specificity of plain radiographs were, respectively, 69.7% and 83.3% compared with the 100% sensitivity and specificity of the CT scan. There were cases of both false-negative and false-positive results in x-rays of the wrist: CT scan revealed 10 fractures not seen on x-ray and 2 fractures were noted to be falsely positive by the scans. The study also noted that the sca-

![Figure 3. Diagram Of The Alignment And Spacing Of The Carpal Arches](image)


**Figure 4. The PA View**

In the PA view, the lunate has taken on a more triangular shape, and the carpal arcs are completely disrupted.

**Figure 5. The Lateral View**

The lateral view shows the capitate outside of the cup of the lunate, but the lunate is essentially in normal position.
phoid and the triquetrum were the most commonly fractured carpal bones.

This study presents supporting evidence that emergency clinicians should not hesitate to obtain CTs for patients with physical examinations that differ from what plain radiography reports. This additional step would reduce the number of incorrect sprained wrist diagnoses made in the ED, ensuring appropriate follow-up and avoiding permanent disability. Obviously this will slow the throughput of these patients through the ED, result in many CT scans with negative results at a high financial cost, and increase the time to the scanner for other waiting patients.

ED Management Of Wrist Injuries

Scaphoid Fractures
Scaphoid fractures comprise 60% to 80% of all carpal fractures. Because the scaphoid forms a bridge between the carpal rows, it must withstand dramatic forces across its waist during forced extension of the forces across its waist during forced extension of the wrist. Although common, scaphoid fractures can be difficult to visualize on film. In many series, 10%-20% of scaphoid fractures are not visible on the initial x-rays. However, these results have not been reproduced by other researchers.

This study presents supporting evidence that additional step would reduce the number of incorrect wrist diagnoses made in the ED, ensuring appropriate follow-up and avoiding permanent disability. Obviously this will slow the throughput of these patients through the ED, result in many CT scans with negative results at a high financial cost, and increase the time to the scanner for other waiting patients.

Figure 6. The Scaphoid View

The scaphoid view (Figure 6) allows a better view of the length of the scaphoid; compare with the PA or the oblique views.


Figure 7. The Pronated View

The pronated view (Figure 7; top) presents an alternative view of the radial side bony elements, whereas as the supinated view (Figure 8; bottom) presents the ulnar elements.

Reproduced with permission from: Harris JH, Harris WH, eds. The Radiology of Emergency Medicine. 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:377. Fig. 6.2c and Fig 6.2d.
wrist. Although common, scaphoid fractures can be difficult to visualize on a radiograph. In many series, 10% to 20% of scaphoid fractures are not visible on the initial x-rays.\textsuperscript{41-42} However, a significant percentage of these missed fractures may be obvious on radiographs taken 2 weeks post injury.\textsuperscript{43} (See Figures 9 and 10.) Some studies suggest that multiple views may enhance radiographic visualization. In 1 study of 90 ED patients, 44 individuals had evidence of scaphoid fracture on a 4-view series (PA, lateral, PA with ulnar and radial deviation).\textsuperscript{41} When the authors added 25° supination and pronation views, they detected an additional 11 scaphoid fractures, making the 6-view radiography series 100% sensitive for scaphoid fracture.\textsuperscript{41} However, these results have not been reproduced by other researchers.

In addition to special views, inspection of the soft tissues may provide clues to scaphoid injury. The scaphoid fat stripe lies parallel and just radial to the scaphoid on the PA view. It should be slightly bowed inward toward the bone; obliteration or outward deviation of the stripe may suggest occult fracture. However, false-negative rates of 15% to 30% and false-positive rates of 12% to 32% limit the utility of this sign.\textsuperscript{44-47}

Missed Scaphoid Fractures

A single artery that enters the distal end supplies the scaphoid bone; thus, a fracture can easily interrupt this tenuous blood supply. Inappropriate treatment because of a missed scaphoid fracture can result in an avascular necrosis of the proximal fragment. Unfortunately, even in recognized fractures that are treated appropriately, the chance of nonunion or necrosis resulting in persistent pain and loss of mobility is 5% to 12%.\textsuperscript{48-50} The complication rate increases to 40% to 88% when the fracture is not recognized and immobilized.\textsuperscript{48-50} These grim odds have prompted some authors to suggest prolonged immobilization for all patients with scaphoid tenderness, regardless of radiographic findings.\textsuperscript{51}

On the other hand, aggressive immobilization is not without consequences. Only 6% to 20% of patients placed in plaster for a presumed occult scaphoid fracture actually prove to have a fracture at follow-up.\textsuperscript{52} Furthermore, 6 weeks of immobilization can represent a significant inconvenience for the patient.

Imaging Strategies

Scaphoid fractures are often undetectable on initial radiographs. The prevalence of occult scaphoid fracture at initial examination has been estimated to be 4% to 26%.\textsuperscript{17} Because of this, researchers formerly suggested immobilizing all patients with scaphoid tenderness and obtaining a repeated x-ray at 2 weeks post injury.\textsuperscript{52} Such recommendations were

**Figure 9. The PA View**

![The PA view appears normal.](image1)

**Figure 10. The Pronated View**

On the pronated view, the fracture line is clearly visible, though subtle. It is also visible on the scaphoid view (not shown).
commonly made before the widespread availability of MRI or even bone scans. This begs the question, “Can early use of these technologies supplant prolonged immobilization?”

**Bone Scans**
Bone scanning became a popular tool soon after it was introduced. The timing of the scan for patients with potential scaphoid fracture is an important consideration. Scans obtained too soon (1-3 days) after injury yield false-positives due to periosteal reaction, edema, bone bruising, and other conditions. Scans obtained 14 days after injury are more sensitive than conventional radiography, but this mandates a 2-week period of immobilization before the scan. In 1 series of 100 patients, scans obtained on day 4 were 100% sensitive and 92% specific (and had a positive predictive value of 65%). Despite the value of early bone scans in this study, many hand surgeons use nuclear studies at 2 to 4 weeks and limit them to patients for whom the x-ray and clinical picture remain ambiguous.

**Magnetic Resonance Imaging**
MRI has become standard in the evaluation of suspected scaphoid fractures. It is nearly 100% sensitive, provides good anatomic detail, and is accurate in the acute setting.

Studies of MRI within 7 days of injury have yielded sensitivity rates of 100% compared with 6-week radiologic follow-up using plain radiographs. In 1 prospective, randomized study, the combination of repeated clinical examination and plain radiography was as sensitive as MRI in the detection of occult scaphoid fracture—only the injury was diagnosed by day 3 in the MRI group versus day 38 in the group treated using clinical examination and plain radiograph. On the downside, MRI is expensive, and no one has analyzed the cost/benefit ratio of routine MRI in the setting of suspected scaphoid fracture. However, some argue that early MRI will prevent unnecessary immobilization.

A 2008 study offers insight into the current management of suspected scaphoid fractures and the economical decisions encountered with potential wrist fractures. We know that anatomical snuffbox tenderness offers a high sensitivity in detecting fractures but a low specificity. Additionally, initial plain radiographs have a low sensitivity and miss up to 25% of fractures. Previous management called for patients with snuffbox tenderness and negative plain radiographs to be immobilized until radiographs were repeated 2 weeks later, leading to a high rate of unnecessary immobilization. The study assessed 200 patients clinically suspected of having a scaphoid fracture and found that only 16% were actually proven to have one.

The positive predictive value of initial clinical examination was found to be 16% and the negative predictive value of the initial plan radiographs was 84%. For each patient with a fracture, 5.25 patients were overtreated. The study also assessed different radiological options to assess these wrist injuries to reduce the amount of overtreatment. MR and CT both exhibited comparable rates of fracture detection, and MR has the added benefit of detecting soft tissue injuries and avoiding radiation. Ultrasonography, although rapid, accessible, and inexpensive had the greatest number of false-positives and false-negatives for fracture detection.

The article concluded that traditional management offers low diagnostic accuracy and routinely overtreats the majority of patients while offering few negative outcomes, such as nonunion. Although CT and MR offer good detection rates and would greatly reduce the cost of unnecessary immobilization to the economy and health care system, the article advocates more medicoeconomic research to be conducted to assess the opportunity cost of routinely imaging these potential fractures.

**Determining Which Study To Choose**
One study compared MRI with bone scans performed an average of 19 days after suspected scaphoid fracture. Both were extremely accurate. The nuclear studies had 1 false-positive versus none in the MRI group; on the other hand, 2 people were unable to complete the MRI because of claustrophobia. Other studies also confirm that either bone scan or MRI delivers accurate information in the setting of suspected scaphoid fracture. Although MRI seems to have the advantage of earlier reliability and better anatomic detail, bone scans are probably more widely available and less expensive.

One 1995 study published in the *Journal of Nuclear Medicine*, examined the cost of various diagnostic strategies in suspected scaphoid fractures. The authors suggest that the most efficient approach to the evaluation of patients with suspected scaphoid fractures consists of x-rays on day 1 followed by delayed bone scintigraphy in patients with initial scaphoid x-rays not revealing a fracture.

**Treatment**
What remains alarming about these studies is the number of scaphoid and other carpal fractures missed on plain radiographs but identified using advanced imaging techniques—a prevalence ranging from 20% to 30% and even higher. Moreover, all of these data are probably moot vis-à-vis emergency practice. When patients have clinical signs of scaphoid fracture (snuffbox tenderness, pain with axial compression of the thumb, pain on palpation of the tubercle, and so on), treat them as if they have a fracture—even in the presence of a x-ray with a negative finding. This means immobilization and orthopedic follow-up in 7 to 10 days. The consultant may then determine the appropriate study—
An Evidence-Based Approach To Traumatic Emergencies

whether it be MRI, bone scan, clinical examination, or simple radiography. Failure to immobilize these injuries in the emergency setting contributes to the already high amount of malunion and avascular necrosis.

There is persistent controversy about the ideal immobilization for scaphoid fractures. Virtually all of the studies addressing this issue have significant weaknesses, the most common being failure to define inclusion criteria other than snuffbox tenderness. Most studies are small, so that 1 or 2 misreads considerably alter the statistical outcome.

The basis of the controversy is that rotation of the forearm applies shear to the scaphoid. Long arm casts prevent rotation of the forearm, but they are significantly more limiting and uncomfortable than short arm casts. Clinical studies are scarce and contradictory. At least 1 clinical study (randomized, 100 nondisplaced scaphoid fractures, long vs. short casts) showed significantly shorter times to union when a long arm spica (which includes immobilization of the thumb) was used.66 Another study showed no difference in outcome; however, this study included displaced fractures, which tend to do poorly anyway.67 A review of the literature suggests using a long arm spica for displaced fractures (> 1 mm displacement) and a short arm spica for nondisplaced fractures.68 A thumb spica splint as opposed to a cast is probably adequate in the acute setting.

A study assessing injuries that are misdiagnosed as sprained wrists in the ED determined that sprained wrist is the second most common initial diagnosis in patients with diagnostic error made in the ED.69 Two percent of patients whose injuries were diagnosed as a sprained wrist had a more severe injury: this is particularly alarming because wrist injury is one of the most common chief concerns that we see in the ED. Greenstick or torus fractures of the distal radius represented 42% of these diagnostic errors, whereas scaphoid fractures and other fractures of the distal radius make up the majority of the remainder. Fortunately in this study, none of the diagnostic errors resulted in additional harm to patients because torus fractures of the distal radius and scaphoid fractures do not need immediate treatment to achieve acceptable outcomes.

A prospective, randomized trial of 201 consecutive patients randomized torus fractures of the distal radius to a traditional forearm plaster cast or a wrist splint. The results revealed that there was no difference in outcome between the 2 types of immobilization.70 Thus, patients misdiagnosed with sprains who actually have torus fractures will have similar outcomes in splints used to treat wrist sprains. Another study examining 285 scaphoid fractures found that there was no increase in the prevalence of nonunion or delay in bony union as long as scaphoid fractures were immobilized within 4 weeks.71 However, a delay more than 4 weeks led to a high rate of fracture complications. We can conclude that if an emergency practitioner is unsure about a diagnosis following a wrist injury, timely orthopedic follow-up will suffice to dictate proper management as well as uncover the proper diagnosis, as fractures will be persistently painful.

Orthodox medicine has not found an answer to your complaint. However, luckily for you, I happen to be a quack.
—Richter cartoon caption

Other Carpal Fractures

Triquetral Fractures
Triquetral fractures, the second most common type of carpal fracture, occur with both direct trauma and with FOOSH injuries. Dorsal chip fractures are due to hyperextension when the ulnar styloid is jammed into the dorsum of the triquetrum. This produces tenderness just distal to the ulnar styloid. These fractures require splinting and generally do well. Transverse fractures are less frequent and more ominous. Fracture through the body of the triquetrum is associated with perilunate, scaphoid, and ligamentous injury. Patients with triquetral fractures require a long arm splint and early referral.

Hamate Fractures
Hamate fractures, which account for 2% to 4% of carpal fractures, are becoming more common because of the popularity of racket sports and golf.72 The hook of the hamate projects from the body into the palm and defines the ulnar wall of the carpal tunnel as well as serving as a pulley for the extrinsic flexors of the ring and small fingers. The hook can break with direct impact, as in a fall on the palm or crush injury, or mechanisms where the extrinsic flexor tendons are forced through the hook, such as in racket, bat, or club sports. (The hamate is at particular risk when a golfer firmly strikes the sod in a futile attempt to gain an additional 30 yards.)

Hamate fractures can be difficult to visualize on standard views. If you suspect this injury, order a carpal tunnel view (although this is often difficult to perform in the painful acute setting) or a supinated oblique view.72 One recent study of 16 patients with a fracture of the hook of the hamate examined the value of various radiographic views.73 Of 13 patients, the routine PA view raised the suspicion of fracture in 4 (31%); of 14 patients, the carpal tunnel view demonstrated the fractures in 6 (43%); but the supine oblique radiographic view was the most valuable of the plain radiographs. Of 10 patients, it showed fractures in 8 (80%). However, in this small series, CT proved to be the most accurate study of all.

Missed injuries may lead to nonunion, stress, or rupture of flexor tendons as well as ulnar neuropathy. Immobilization and early referral are adequate treatment in the ED. Although no one has compared
This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Clinical Pathway: Evaluation Of Wrist Injuries  

(Continued from page 111)

**Suspicion of hamate hook injury?**
- Racket or golf club swing mechanism
- Tenderness over hypothenar eminence
- Pain in hypothenar eminence with flexion of fourth and fifth fingers

**YES**

Consider special views:
- Carpal tunnel (Class II-III)
- Supine oblique (Class II)

**NO**

**YES**

**Tenderness of wrist after trauma?**

**YES**

- Standard wrist films (PA and lateral) (Class I-II)
- Oblique views (Class II-III)

**NO**

**YES**

- High mechanism of injury
- Tenderness of over scaphoid, lunate, or hamate
- Positive Watson’s test (scapholunate instability)
- “Clunking” with ROM wrist

**YES**

- Splint or cast (Class II)
- Thumb spica if signs of scaphoid injury (Class II-III)
- Early referral (Class II)
- Emphasize the importance of follow-up (Class indeterminate)

**NO**

- Splint (Class III)
- Refer to primary care physician or orthopedist (Class III)

**Exit pathway**

**Is there a fracture?**

**YES**

Go to “Clinical Pathway: Management Of Wrist Fractures And Dislocations,” page 113

**NO**

**Negative x-rays**

**X-ray positive for fracture or dislocation**

Go to “Clinical Pathway: Management Of Wrist Fractures And Dislocations,” page 113

For Class of Evidence Definitions, see page 1.

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Clinical Pathway: Management Of Wrist Fractures And Dislocations

Lunate or perilunate dislocation

Emergent/urgent surgical consult (Class II)

Radius fracture

High risk?
- Angulation of > 20°
- Ulnar separation
- Dorsal comminution
- Shortening of the radius > 5-10 mm
- > 2 mm of articular step-off
- Median nerve dysfunction

High risk

Urgent surgical consultation (within hours) (Class II-III)

Not high risk

Splint and refer (Class II-III)

Scaphoid fracture

- Displaced fractures (> 1 mm): Long arm spica splint or cast (Class II-III)
- Non-displaced fractures: Short-arm spica splint or cast (Class II-III)
- Refer all

Other carpal fractures

- Immobilize:
  - Volar splint for most carpal fractures (Class indeterminate)
  - Ulnar gutter splint for hamate fractures (Class indeterminate)
  - Early referral (Class II-III)

Carpal instability or scapholunate disruption (widened scapholunate gap and cortical ring [or signet ring] sign on x-ray)

- Immobilize:
  - Volar splint (Class indeterminate)
  - Early referral (Class II-III)

For Class of Evidence Definitions, see page 1.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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the various splints with their effect on outcome, an ulnar gutter splint should reduce pain if it immobilizes the wrist as well as the fourth and fifth fingers (whose tendons course beneath the hamate hook).

**Lunate Fractures**

Lunate fractures are uncommon. The mechanism is usually a fall, and patients may complain of diffuse or central wrist pain. Palpation of the bone distal to Lister’s tubercle should elicit pain. Lunate fractures can be difficult to visualize on radiographs. As with the scaphoid, suspicion of lunate fracture mandates immobilization until it is ruled out at follow-up. Problems due to a tenuous blood supply threaten the lunate. Long-term complications include avascular necrosis (Kienbock’s disease). This leads to long-term disability, collapse of the carpal space, migration of the capitate and scaphoid, and disruption of the normal wrist mechanics. Acutely, these fractures (or suspected fractures) need to be splinted, and the patient should be referred to an orthopedist.

**Capitate Fractures**

Capitate fractures are rare because of the bone’s protected location in the center of the wrist. They occur in dorsiflexion injuries, especially when radial deviation forces the radius into the capitate, which can lead to fracture or dislocation. Displaced fractures need referral and reduction, whereas nondisplaced fractures require simple immobilization and referral.

**Trapezium Fractures**

Trapezium fractures are rare and occur most often through direct trauma. Movement of the thumb will be limited. A thumb spica splint is adequate until the orthopedic consultant sees the patient at follow-up.

**Ligamentous Injuries**

Ligamentous wrist injuries can lead to significant long-term sequelae; unfortunately, they are frequently overlooked. This may be due to lack of familiarity in how to detect these injuries on physical examination and because x-ray findings may be subtle. Disruption of these wrist stabilizers can lead to migration of the carpal bones, disruption of the normal mechanics, arthritis, and chronic pain. Once chronic sequelae develop, the outcome is usually poor despite surgical treatment. Orthopedists often discuss ligamentous injuries in terms of the injury location—that is, dorsal intercalated segment instability (DISI) and volar intercalated segment instability (VISI).

The wrist has no inherent architectural stability; no ball and socket, mortise, or hinge is involved. Without the ligaments, the carpi are nothing more than a clattering bag of bones. In extension, the volar ligaments progressively tighten between the radius and the carpal rows. At maximal extension, the volar extrinsic ligaments are taut and the space of Poirier (located between the proximal and distal volar extrinsic ligaments) is open. As the distal row slides dorsally over the proximal row, the scaphoid sustains greater stress. Ultimately, the dorsal rim of the radius crashes into the scaphoid waist. Forced extension beyond this breaking point will damage ligaments, bones, or both. The amount of radial or ulnar deviation, rotation, and the location of impact and duration of load will determine the nature of the structural failure.

Although the most familiar manifestation of this sequence is the scaphoid fracture, a wide range of ligamentous injuries, dislocations, and fracture-dislocations can be overlooked. Delay in diagnosis may allow the ligaments to fibrose and will limit repair options. Physical examination is useful for diagnosing ligamentous wrist injuries (as described later in the text). Plain radiographs may be inadequate, yet a number of other imaging techniques may fill this diagnostic void. These include CT and trispiral tomography, arthrography, videofluoroscopy, and MRI.

**Scapholunate Injury**

The mechanics of ligamentous wrist injury have been described and staged by several authors, including Mayfield, who vividly describes the process: “In essence, the scaphoid and distal carpal row are progressively peeled away from the lunate.”

The first ligamentous complex to rupture is the scapholunate, causing what is variably described as scapholunate instability, scapholunate dislocation, and rotary subluxation. These descriptive names invoke various degrees of damage to the scapholunate and radioscapoid ligaments, but the principle is essentially the same.

The degree of instability will dictate the findings. Physical findings may include tenderness at the scapholunate joint just ulnar to the snuffbox or instability of the scaphoid elicited by the scaphoid shift or Watson’s test. To perform this test, apply upward pressure to the scaphoid tubercle (push from palmar toward dorsal) while moving the hand from ulnar to radial deviation. With scapholunate instability, the scaphoid may sublux dorsally, reproducing pain and movement of the bone. However, there are several drawbacks to Watson’s test. Not only is it painful in the acute setting, but also it seems to have low specificity. In 1 study, 36% of unaffected individuals had positive findings on the scapholunate shift test.

**Radiology**

The expected radiographic findings of scapholunate injury on the PA view include a widened scapholunate gap, and a cortical ring (or signet ring) sign as the lunate foreshortens and the tubercle is viewed on end. (See Figures 11 and 12.) The lateral view may show an increase in the scapholunate angle. (See Figure 13,
Routine radiographs may miss signs of this injury. A clenched fist view may show widening of the scapholunate space as the capitates is forced proximally between the scaphoid and lunate.\(^{79,82}\)

**Lunate And Perilunate Dislocations**

If the scaphoid suffers fracture or ligament damage, it can no longer stabilize the wrist. At this point, further damage to the radiocapitate ligament, part of the volar extrinsic group, allows the capitates to slip out of its position in the lunate cup, leading to perilunate dislocation. Progressive shearing forces lead to rupture of the scapholunate, capitates-lunate, and lunate-triquetral connections. This destabilization may also encompass fracture of the involved bones, usually the scaphoid or triquetrum, leading to a fracture-dislocation.

In spite of the forces involved and seemingly obvious radiographic findings, perilunate and lunate dislocations are commonly missed.\(^{27,28}\) In 1 series of 166 perilunate injuries, 25% were missed initially, including both dislocations and fracture-dislocations.\(^{83}\) Outcomes were worse when diagnosis and treatment were delayed by more than 7 days.

**Perilunate Dislocations**

Unless there has been spontaneous reduction, fracture-dislocations should be evident on radiograph. On the lateral view, the capitates will no longer sit in the same line with the lunate, midshaft radius, and metacarpals; it will be outside the cup of the lunate. On the PA view, look for a triangular (as opposed to quadrangular) lunate and a disruption of the arcs of the carpal bones. (See Figure 4 and Figure 5, page 106) Also look for associated carpal fractures.\(^{83}\)

**Lunate Dislocations**

Further disruption of the ligamentous support leads to lunate dislocation in which the lunate is torn from its normal position on the radius. This is most notable on the lateral view, where the lunate is “spilling over” toward the palm, rather than cupping the capitates. (See Figures 14 and 15; also see Figure 16, pages 116 and 117) Like any dislocation, lunate and perilunate dislocations need to be reduced sooner rather than later (that is, within hours).\(^{84}\) Once reduced, the patient may still require a surgical procedure at a later time. Specialty consultation is mandatory.

**Radius Fractures**

Distal radius fractures are the most common upper extremity fracture and represent a large portion of the overall fractures seen in the ED. The older literature depicted these as simple injuries that enjoyed good outcomes. This is true in the set of patients originally defined by Colles in 1814, which consisted of older people who had reduced functional expectation and whose reduced life expectancy gave them

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**Figure 11. PA View, Scapholunate Injury**

In the PA view (Figure 11), scapholunate injury may be detected when the gap between the bones widens. The finding may be subtle.

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**Figure 12. PA View, Scaphoid Ring**

The only obvious abnormalities on this PA view are the projection of the scaphoid ring (or signet ring) and that the scaphoid is somewhat foreshortened, suggesting that it may be rotated out of its normal.
Acute injury to the ligaments that hold the scaphoid in relation to the other carpal bones may allow the scaphoid to rotate out of position.


The lunate is now disoriented in relation to the radius on the lateral view (Figure 14), and the capitate is no longer coaxial.

On the PA view (Figure 15), the lunate is triangular rather than its normal quadrangular appearance.

Figure 15. PA View, Triangular Lunate

Figure 13. The Scapholunate Angle

Figure 14. Lateral View, Disoriented Lunate

less time to develop long-term complications. It may also be a relatively minor injury in the pediatric age group. In both the young and the old, the carpal bones are spared as the osteopenic or immature radius gives way under impact.

Because the radius in young adults is neither immature nor osteopenic, these are almost by definition high-energy injuries. It is probably inappropriate even to call distal radius fractures in young adults “Colles’ fractures,” because they differ in terms of associated damage, prognosis, and treatment. Young adults are more likely to have greater soft tissue injury, as well as a higher occurrence of intraarticular and complex fracture patterns, than are children or the elderly. They also have a higher expectation of good functional outcome over a long remaining life span.

Other wrist injuries are often seen in association with distal radius fractures. In 1 study, 68% of patients requiring operative repair of a radius fracture had injuries to the soft tissues, including the TFC, the scapholunate, or the lunate-triquetral ligaments. Pay special attention to median nerve function in patients with Colles’ fractures. In 1 study, severe median neuropathy was present in 13% of 536 fractures, and chronic median neuropathy developed in 23%.

The chauffeur fracture (or Hutchinson fracture) is a break in handlebars. By maintaining a fierce grip on the handlebars, a direct blow or fall on the dorsum of the wrist. It is often the result of a bicyclist or motorcyclist being thrown over the handlebars. This fracture occurs with distal radius fractures. In 1 study, severe median neuropathy was present in 13% of 536 fractures, and chronic median neuropathy developed in 23%.

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The authors included 31 trials totaling 3372 (mainly female patients requiring operative repair of a radius fracture had injuries to the soft tissues, including the TFC, the scapholunate, or the lunate-triquetral ligaments. Pay special attention to median nerve function in patients with Colles’ fractures. In 1 study, severe median neuropathy was present in 13% of 536 fractures, and chronic median neuropathy developed in 23%.

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Over the past decade, surgical procedures have become more frequent in the treatment of these fractures, in an attempt to attain full anatomic correction. A surgical procedure is generally indicated in those with so-called high-risk fractures. "High risk" criteria include fractures with an angulation of more than 20°, ulnar separation, dorsal comminution, shortening of the radius more than 5 to 10 mm, and more than 2 mm of articular step-off. 21,90,91 There is significant controversy about how closely the anatomic configuration needs to be restored and whether this will prevent long-term complications of carpal instability and hand weakness, 93 delayed rupture of finger flexors, 94 chronic pain, 95 neuropathy, 96 cosmetic deformity, or arthritis. 97

Despite years of study, the best approach to distal radial fractures remains unclear. A Cochrane review examined randomized and quasirandomized clinical trials in adults with fracture of the distal radius to determine the most appropriate conservative treatment. The authors included 31 trials totaling 3372 (mainly female and older) patients. The authors stated, "There remains insufficient evidence from randomized trials to determine which methods of conservative treatment are the most appropriate for the more common types of distal radial fractures in adults." 98

**Figure 16. Lunate**

The lunate is now disoriented in relation to the radius on the lateral view, and the capitate is no longer coaxial. On the PA view, the lunare is triangular rather than its normal quadrangular appearance.

Makhni assessed the radiographic success of nonsurgically treated distal radial fractures in different age groups. Nonsurgical management included casting alone or closed reduction with immobilization. When fractures were evaluated 8 weeks later, there was a significant correlation between displacement rate and patients’ age in the closed reduction group. Patients 65 years and older had the highest displacement rate at 89%, patients between 45 and 64 years old had an 81% rate, and patients between 18 and 44 years old had a 58% rate. 99

There was no age correlation in secondary displacement in patients whose fractures were only casted without closed reduction. Emergency practitioners must remain advocates for their patients and ensure they are appropriately referred to orthopedists who will operate if a better outcome is more likely, especially in patients older than 65. We should also remain aware of the high secondary displacement rate within 8 weeks in patients post–closed reduction when they present to the ED with persistent pain or neurological deficit implying malalignment.

**Other Fractures Of The Distal Radius**

There are other named fractures of the distal radius, each associated with a specific mechanism. Rather than naming the fracture, it is more important to identify and describe the lesion in terms of location, displacement, angulation, and comminution, as these parameters determine treatment and prognosis.

**Volar Angulation**

The Smith’s fracture (or reverse Colles’ fracture) occurs with direct blow or fall on the dorsum of the wrist. It is often the result of a bicyclist or motorcyclist being thrown over the handlebars. By maintaining a fierce grip on the handlebars, the patient sustains a distal radius fracture with volar, rather than dorsal, angulation. Treatment criteria are similar to dorsally angulated fractures.

**Radial Styloid Fracture**

The chauffeur fracture (or Hutchinson fracture) is a break in the radial styloid. It is generally due to direct impact on the radial side of the wrist. (The archaic reference to the chauffeur involves a blow from the crankshaft handle of an antique car.) In this injury, the styloid is avulsed, including the attachment of the extrinsic ligaments of the wrist. Therefore, displaced fractures usually mandate open reduction and repair. 100

*History teaches us that men and nations behave wisely once they have exhausted all other alternatives.*

—Abba Eban
Radioulnar Joint Injuries
The distal radioulnar joint includes the TFC and the radioulnar articulation. Injuries to this joint are commonly missed in the acute setting.\(^{101-103}\) Dislocation of the ulna commonly occurs with distal radius fractures and can be an important component of some fracture-dislocations of the forearm. Occasionally, ulnar dislocation at the radioulnar joint occurs without bony injury. The injury can result from falls or axial distraction, as in sudden distraction or rotation (such as suddenly lifting or grasping a fixed object, such as a handrail or banister, against a fall). Radioulnar joint injuries can also result from crush- or wringer-type mechanisms.

To detect radioulnar dislocations radiographically, it is important to get true PA and lateral views (although this may be difficult in the suffering patient). Remember that the ulna has a fixed relationship to the radius in true PA and lateral radiographs. On the lateral view, the dislocated ulna will project either dorsally or volarly to the radius. On the AP, it will overlap the radius and close the radioulnar gap. Other suggestive signs of injury include fracture of the ulnar styloid base (which is associated with TFC injury) as well as radial shortening of 5 mm or more relative to the ulna.\(^{104}\) In cases in which the diagnosis is suspected but radiographs are equivocal, CT of the wrist may be helpful.\(^{102,105}\) This test, however, is usually left to the consultant.

Treatment
Delayed diagnosis makes closed reduction difficult. The key is to identify the dislocation both in isolation and in association with nondisplaced fractures. Reduction of associated fractures will often bring the ulna back into position. Once reduction is achieved, immobilize the arm with a long arm splint to prevent rotation at the injured joint. Damage to the TFC, which is the main stabilizer of the joint, or inability to reduce the joint usually mandates operative repair.\(^{106-108}\)

Special Circumstances
Pediatric Issues
Carpal fractures are extremely rare in the very young. A recent review of pediatric carpal injuries describes

Risk Management Pitfalls For Wrist Injuries (continued on page 119)

1.  “The splint/cast was put on by the [choose one: ortho resident, PA, nurse, med student]. The patient was discharged by the [choose one: nurse, PA, resident]. I thought he told the patient about signs of vascular compromise.” That’s right—he should have. But it was under your authority and supervision; therefore, you should check the final product. Make sure the patient understands the warning signs of vascular compromise (change of color, sensation, pain, significant swelling) and has access to medical care should it occur. Document these instructions, and make sure the patient has access to follow-up. Untreated or undertreated wrist injuries can lead to lifelong complications.

2.  “It was just a nick in the skin. I didn’t think it was an open fracture.” Not every open fracture needs to be washed out in the OR. But that’s a decision best made by a surgeon. Osteomyelitis is low on everyone’s wish list.

3.  “At the most, the guy will have some chronic pain in his wrist. I didn’t think to ask if he was a [choose one: cabinetmaker, aspiring concert violinist, wicked left-handed pitcher being scouted by the Cubs, emergency physician].” Think about it. How much chronic pain would you be willing to tolerate in your job? You might have disability insurance, but that’s no substitute for your job. Treat wrist injuries with respect—immobilize and refer.

4.  “I didn’t document two-point discrimination. She wasn’t complaining of numbness.” The pain from the fracture was more significant to her than the numbness. Maybe her two-point was intact at presentation—maybe not. But you didn’t check, and the neurovascular exam wasn’t documented.

5.  “There was a lot of swelling. How was I supposed to feel the pulse?” This is not an uncommon problem. If swelling obscures the pulse at the wrist, sometimes you can feel it in the snuffbox. Consider using a Doppler to detect the pulse. If these are absent, you still have access to capillary refill or the Allen test.

6.  “It was late. I didn’t want to wake my hand guy up for a wrist sprain, because I couldn’t be sure that the lunate was dislocated.” By the time the hand specialist found out about the injury, it was the next afternoon. Wrist dislocations do better if reduced early. Not every wrist injury needs to be seen emergently, but it is critical to recognize the ones that do.
carpal injuries in terms of case reports or small series. There are few carpal injuries because these “bones” are more cartilaginous than calcified and are thus relatively resistant to injury. Because the radius growth plate is weaker than the joint capsule, energy transmitted from a fall leads to epiphyseal rather than carpal injury. This produces torus and greenstick fractures of the radius. Torus (doughnut-shaped) fractures are best appreciated as a tiny bump on the cortex of the distal radius on either the PA or lateral views. As the child ages and growth plates close, injury patterns approach those of adults. In older children, carpal injury will occur, and in young adults, scaphoid fracture is the most common.

A recent randomized controlled trial (RCT) with 82 pediatric patients assessed the immobilization of torus fractures of the distal forearm. The results indicated that fiberglass volar slab immobilization was associated with increased duration of pain (6 days) compared with plaster casts (3 days) and a longer disability time until resuming routine activities (at 2 weeks, only 67% had resumed normal activities compared with 95% in the casts group). Another RCT aimed to change the current management of wrist buckle fractures. A buckle fracture occurs when the bony cortex is compressed inward on one side while the other cortex remains intact. Old management dictated 2 to 4 weeks in a short arm cast, although currently casts and splints are both commonly used. The aim of the RCT was to compare the outcome in children with distal radius or ulna buckle fractures placed in removable splints with children placed in short arm casts. Casts result in more disability during immobilization, limiting mobility and potentially unnecessarily burdening a family when a more manageable splint offers equivalent pain relief.

Eighty-seven children 6 to 15 years old were randomly assigned to the 2 different immobilization options. The results revealed that splints had less impact on a child’s daily functioning, such as bathing and daily activities, and children in splints were able to return to sports quicker without any undesirable effects such as increased pain or refractures.

Children with wrist buckle fractures do not need 3 weeks of constant immobilization, and although

### Risk Management Pitfalls For Wrist Injuries (continued from page 118)

7. “There was no snuffbox tenderness, and the x-ray was negative. I was confident it wasn’t a scaphoid fracture.”

You were right. It wasn’t a scaphoid fracture—the lunate was broken! You failed to do a complete examination and take adequate precautions (immobilization and referral). The patient went home with a “wrist sprain,” never had short-term follow-up, and developed permanent disability because of Kienbock’s disease (osteonecrosis of the lunate). Examine the entire wrist. FOOSH mechanisms can result in a variety of different injuries. Identify the likely injuries by history and physical examination, and order any special views that will help you make a diagnosis.

8. “It was a simple Colles’ fracture in a guy who fell off his bike in a race. I’ve treated dozens of radius fractures in elderly people over the past year just by splinting and getting a two-week follow-up.”

Elderly women fall down after tripping on the sidewalk—low impact, brittle bones. They don’t generally hit the ground at 30 MPH, like this cyclist did. The distal radius fracture has a much worse prognosis in high-energy injuries. They may be associated with carpal injuries, dislocations, or neurovascular damage. Perform a scrupulous examination of the wrist and the x-rays to detect high-risk findings.

9. “I didn’t x-ray his wrist because he said that he didn’t feel any glass in the wound. Plus, when I explored the wound, there was too much blood for me to see anything.”

A patient who is cut by shattered glass can harbor a foreign body. The patient’s testimony as to whether or not there is a foreign body is notoriously inaccurate. If you’re unable to visualize the base of a wound, use a tourniquet or get an x-ray if glass is involved.

10. “He could make a fist. That means the tendons were intact.”

Not really. Patients with complete transection of a flexor superficialis tendon can still clench their fist using the deep finger flexors. The wrist flexors can be cut and the patient can still flex his wrist using the finger flexors. When performing the physical examination, isolate the deep from superficial tendons in order to be sure of proper function. When exploring the wound, look for tendon injury even if the patient can move his or her fingers. A patient with a 90% tendon rupture may still have finger movement.
adherence may prove problematic with removable splints, it seems that splints should become the standard of care for this injury.

The most common pitfall in dealing with wrist injuries among children involves injury to the growth plates, especially in the radius. One study revealed that 87% of 38 children for whom wrist “sprain” was diagnosed in fact had Salter type I injuries (see Table 2) of the distal radius. In children, fracture lines may be obscure, especially if the fracture occurs through the growth plate. Evaluating the fat stripes of the wrist can be helpful in detecting otherwise occult injury. The pronator quadratus muscle attaches at the distal third of the radius and ulna and is associated with an overlying layer of fat. This fat stripe is best seen on true lateral projection (see Figures 17 and 18) and normally bows slightly toward the bone (as in Figure 18). Outward bulging or obliteration of the fat stripe can signify bleeding or edema in the underlying bone (as in Figure 17). In 1 study, this sign was positive in 74% of Salter type I radius fractures. Comparison views of the opposite wrist may also be helpful in evaluating epiphyseal injury. Treatment outcomes are generally good.

**Open Injuries Of The Wrist**

The most significant open injuries of the wrist usually involve the volar aspect. Here is where the tendons, nerves, and vessels course. A careful distal examination of range of motion and neurovascular supply is essential. Although foreign bodies may be detected on wound exploration, consider the use of diagnostic imaging when the risk of foreign bodies is high. Plain radiographs will detect glass and metals, whereas MRI and ultrasonography are useful for non-radiopaque substances such as wood or plastic.

Wounds requiring repair will need to be anesthetized, cleansed, and then explored to identify...
retained foreign bodies or tendon injuries. Because tendons can retract into the forearm, examine the wrist in full extension and look at the base of the wound during the full range of motion for the appearance of a tendon stub. The most superficial tendon in the wrist is the palmaris longus. This tendon is located in the middle of the volar wrist. It becomes very prominent when the wrist is partially flexed while the patient touches his or her thumb and fifth finger together. Interestingly, 16% of patients may be missing this tendon in either hand, and in an additional 9%, the absence may be bilateral. Division of the palmaris longus tendon is rarely clinically significant except when there is injury to the median nerve, which lies beneath. Lacerations of other flexor tendons require surgical consultation.

The father of modern hand surgery, Sterling Bunnell, once suggested that trying to repair a hand wound without a tourniquet was like “trying to fix a Swiss watch in a bucket of ink.” When exploring the wrist, consider the use of a tourniquet to provide a bloodless field. Because most EDs lack an automated pressure tourniquet, a blood pressure cuff will do. Have the patient lie on the gurney with the arm held directly overhead—that is, sticking straight up from the stretcher. Place a blood pressure cuff around the arm and wrap tape completely around the cuff to keep it from popping off. Have the patient forcefully pump, then clench his or her fist to exsanguinate the forearm (like Bruce Lee in Fists of Fury). Then inflate the cuff above systolic pressure and begin the wound exploration. Limit tourniquet time to 10 minutes to avoid ischemic injury and patient discomfort.

Pain Management

Pain management is an important and often overlooked aspect of wrist injuries. It may be of special significance in those with crush injuries, amputations, and fractures. Opioid analgesics are useful and may be given intravenously, intramuscularly, or orally depending on the severity of the pain. The hematoma block is another valuable technique. It requires manipulation. After identifying the fracture site by palpation and prepping the skin with iodine, insert a needle into the bony deficit and aspirate blood. Then infiltrate 5 to 10 cc of bupivacaine or lidocaine into the fracture site. Most patients achieve significant relief within 15 minutes. If the orthopedist is planning to come to the ED to reduce the fracture, coordinate the timing of the hematoma block appropriately.

Disposition

After an attentive examination and review of the x-rays, the vast majority of wrist injuries can be safely discharged from the ED. Most fractures or suspected fractures can be splinted, and the patient can be sent home. Provide clear instructions regarding splint care, and warn patients about any neurovascular changes that warrant a return to the ED.

Some injuries necessitate emergent orthopedic evaluation. These may include lunate and perilunate dislocations, open fractures, any fracture with neurovascular compromise, and grossly displaced fractures. These are injuries in which early reduction or a surgical procedure may improve outcome. Notably, these are the same injuries that are most often missed on initial evaluation.

Most other wrist injuries, both fractures and ligamentous trauma, can be immobilized, and the patient can then be discharged with follow-up. This applies to simple fractures and even to scapholunate separation that may ultimately need surgical repair. Disposition may depend on factors other than the anatomic injury. Bilateral fractures, or a wrist fracture in an elderly person who is walker dependent, may warrant hospital admission until appropriate home help is ensured.

Summary

Although wrist injuries rarely represent a threat to life, they remain a unique challenge for emergency clinicians. The fact that they are more common but less urgent than other conditions seen in the ED can lull the unwary emergency clinician into a false sense of security. However, the complex anatomy of the wrist, combined with the high level of manual dexterity most people require, makes the management of wrist injuries a virtual minefield for emergency clinicians. Vigilance is a must.

Mechanism of injury and other data obtained during the history and physical examination provide essential clues for the diagnosis and management of wrist injuries. Radiography is almost always required; emergency clinicians must insist on adequate radiographs and order the proper views for the given scenario. Be systematic when evaluating the radiographs. Furthermore, be aware that injuries to the ligaments, muscles, and soft tissue can also lead to long-term sequelae if not managed properly.

Although it is neither cost-effective nor necessary to “splint and refer” all patients with wrist injuries, it is generally better to err on the conservative side. Be sure the patient understands the discharge instructions—especially the importance of follow-up with the appropriate consultant, if indicated. Provide written discharge instructions,
and be sure to document each step of the patient encounter thoroughly.

The management of wrist injuries is rarely clear-cut. Fortunately, though, a thorough and systematic approach to the evaluation and disposition can lead to better outcomes for the patient and emergency clinician alike.

References

Evidence-based medicine requires a critical appraisal of the literature based on study methodology and number of participants. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, is included in bold type following the reference, where available. In addition, the most informative references cited in the chapter, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.


40. You JS, Pil S. The usefulness of CT for patients with carpal navicular fractures. *Clin Orthop.* 2007;465:615-618. (Comparative; 67 patients)


47. Cetti R, Christensen SE. The diagnostic value of displacement of the fat stripe in fracture of the scaphoid bone. *Hand.* 1982;14(1):75-79. (Retrospective; 125 patients)


95. Field J, Atkins RM. Algodystrophy is an early complication of Colles’ fracture: what are the implications? J Hand Surg Br. 1997;22(2):178-182. (Case-control; 100 patients)


**CME Questions**

49. Fractures at the radial or ulnar styloid are significant because:
   a. They will be the most cosmetically apparent after healing.
   b. The extrinsic ligaments that stabilize the carpals originate there.
   c. They are most likely to become infected.
   d. There is a risk of avascular necrosis.

50. Supinated oblique views are useful for:
   a. Reviewing the scaphoid from a different angle
   b. Checking the alignment of the radius and ulna
   c. Alternative views of the hamate and pisiform
   d. Alternative views of the trapezium

51. What is the advantage of a long arm spica over a short arm spica?
   a. It prevents rotation of the forearm in complex scaphoid injuries.
   b. It makes it more likely that the patient will seek medical attention for splint removal.
   c. It bills better.
   d. It protects the elbow joint.

52. Which of the following is a common pitfall in the management of pediatric wrist injuries?
   a. Not examining the wrist carefully to know what injury to suspect
   b. Diagnosing a Salter injury at the distal radius as a “sprain”
   c. Being intimidated by the absence of calcification in the carpi
   d. All of the above

53. The cortical (or signet ring) sign signifies:
   a. The sound that a healthy bone makes when tapped
   b. Abnormal scaphoid alignment
   c. Abnormal triquetral position
   d. Artifact at midproximal fourth phalanx

54. An injury sustained while swinging a bat or club to hit a ball should raise suspicion for which type of injury?
   a. Scaphoid fracture
   b. Triquetral injury
   c. Dislocation around the lunate
   d. Hamate hook injury

55. Severe pain at the wrist sustained in a fall from a third-floor scaffolding should raise suspicion for which type of injury?
   a. A high-energy wrist injury
   b. A shoulder dislocation
   c. A life-threatening blunt abdominal injury
   d. All of the above

56. Which of the following is the most common type of carpal fracture?
   a. Scaphoid
   b. Lunate
   c. Hamate
   d. Triquetrum

57. Most wrist injuries are caused by:
   a. Motor vehicle crashes
   b. A fall on an outstretched hand
   c. Typing for long stretches of time
   d. Sports and other pastimes

58. The proximal arch includes all of the following except:
   a. The hamate
   b. The scaphoid
   c. The lunate
   d. The triquetrum
   e. The pisiform

59. The distal row includes all of the following except:
   a. The trapezium
   b. The trapezoid
   c. The capitate
   d. The hamate
   e. The pisiform
60. In patients with wrist injuries, which of the following should be determined as part of the patient history?
   a. Preexisting medical conditions such as rheumatoid arthritis
   b. The time of the patient's last meal if an emergent surgical procedure is anticipated
   c. Any current medications/allergies
   d. All of the above

61. Finding a distal radius fracture in a young adult roller hockey player should prompt the emergency clinician to:
   a. Splint the wrist and send the patient home with a diagnosis of Colles’ fracture.
   b. Perform a conscientious search for associated wrist injuries.
   c. Suspect a pathological fracture.
   d. Call for an immediate orthopedic consultation.

62. Which of the following is the best strategy for patients with clinical signs of scaphoid fracture?
   a. Immobilization and orthopedic follow-up in 7 to 10 days, even in the absence of radiographic findings
   b. Immobilization and orthopedic follow-up in 7 to 10 days if a fracture is detected on x-ray
   c. Immediate surgical consult
   d. Discharge the patient with instructions to return to the ED if symptoms worsen
To receive CME credit, complete the Answer Sheet on page 129 or online at www.EBMedicine.net/CME.

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**Please make a copy of the completed answer form for your files and return this copy to the address or fax number listed below.**

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Neck Trauma
1. ____ Describe the importance of early and appropriate airway management; describe the diagnostic approach to vascular injuries by zone of injury in neck trauma; identify and provide initial management for laryngeal injury; and discuss the importance of early recognition of esophageal trauma and the accuracy of available diagnostic modalities.

Orthopedic Sports Injuries
2. ____ List conditions or circumstances that require orthopedic or surgical consultation or referral in patients with sports injuries; describe the appropriate treatment and disposition for common orthopedic sports injuries; describe clinical decision rules such as the Ottawa knee rules that are used to determine the need for radiography; and discuss different techniques for shoulder reduction.

Blunt Abdominal Trauma
3. ____ Name typical mechanisms of injury for solid and hollow visceral trauma; explain the appropriate diagnostic approach based upon the clinical scenario; describe which clinical and laboratory features are useful for patients with blunt abdominal trauma; and adapt the management approach in the context of special patient and clinical circumstances.

Wrist Injuries
4. ____ List both common and rare types of bone, muscle, and ligamentous wrist injuries; explain the indications for radiography and other diagnostic studies in the scenario of wrist injury; describe how mechanism of injury as well as patient age and occupation affect wrist injuries and their management; and discuss appropriate emergency management of wrist injuries, including pain management as well as indications for splinting, referral, and follow-up.

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