

Trauma Reports®

Vol. 5, No. 1

Supplement to *Emergency Medicine Reports, Pediatric Emergency Medicine Reports, ED Management, and Emergency Medicine Alert*

Jan./Feb. 2004

The severely injured trauma patient presents a unique diagnostic challenge. The need to diagnose all injuries is complicated by the need to rapidly proceed with acute resuscitation and treatment of life-threatening injuries. Injuries may be missed or a diagnosis delayed at any stage of the management of the trauma patient. Preventing missed injuries and delays in diagnosis requires understanding of mechanisms of injury and injury patterns, a high index of suspicion for injuries, meticulous physical examination, and careful use and interpretation of imaging studies, as well as systematic, continued review of physical exam findings and studies.

All physicians involved in trauma care should realize that the nature of trauma puts the patient at risk for missed injuries. Emergency department (ED) physicians particularly must be vigilant to accurately assess, rapidly stabilize, and appropriately transport a severely injured patient to the level of trauma care the patient requires. Instead of viewing missed injuries as occurrences that result from inexperience or incompetence, strategies to minimize the occurrence of missed injuries and the resulting consequences are needed.

All aspects of a trauma system must work together to improve patient care.

— The Editor

Introduction

Delayed diagnosis of injury and missed injuries are

feared but unavoidable issues in the care of trauma patients. Life-threatening injuries must be immediately treated, sometimes delaying completion of the diagnostic work-up. The Advanced Trauma Life Support (ATLS) course of the American College of Surgeons provides a structured approach to the management of the injured patient that is

designed to systematically evaluate and identify all injuries.¹ ATLS guidelines mandate two surveys for the trauma patient: 1) the primary survey, which is designed to immediately identify and treat life-threatening injuries; and 2) the secondary survey, which is a head-to-toe search for other injuries.

Despite these widely followed guidelines, missed injuries and delays in diagnosis continue to occur at even the best trauma centers.²⁻⁴

Delayed or Missed Diagnoses: Avoiding these Pitfalls in the Trauma Patient

Author: **Cynthia A. Corpron, MD**, Trauma Research Fellow, Columbus Children's Hospital, Columbus, OH.

Peer Reviewer: **Steven M. Winograd, MD, FACEP**, Attending Physician, Department of Emergency Medicine, St. Joseph Hospital, Reading, PA.

Now available online at www.ahcpub.com/online.html or call (800) 688-2421 for more information.

EDITOR IN CHIEF

Ann Dietrich, MD, FAAP, FACEP
Associate Clinical Professor
Ohio State University
Attending Physician
Columbus Children's Hospital
Associate Pediatric Medical Director
MedFlight
Columbus, Ohio

EDITORIAL BOARD

Mary Jo Bowman, MD
Associate Professor of Clinical Pediatrics
Ohio State University College of Medicine
Attending Physician, Children's Hospital of Columbus
Columbus, Ohio

Larry N. Diebel, MD
Associate Professor of Surgery
Detroit Medical Center
Wayne State University
Detroit, Michigan

Robert Falcone, MD

Senior Operations Officer
Grant Medical Center
Columbus, Ohio

Dennis Hanlon, MD

Director
Emergency Medicine Residency Program
Assistant Professor of Emergency Medicine
Allegheny General Hospital
Pittsburgh, Pennsylvania

Robert Jones, DO, FACEP

Emergency Ultrasound Coordinator
OUCOM/Doctor's Hospital Emergency Medicine
Residency Program
Columbus, Ohio
Attending Physician
MetroHealth Medical Center
Cleveland, Ohio

S.V. Mahadevan, MD, FACEP

Assistant Professor of Surgery
Associate Chief, Division of Emergency Medicine
Stanford University School of Medicine
Stanford, California

Ronald M. Perkin, MD, MA, FAAP, FCCM

Professor and Chairman
Department of Pediatrics
Brody School of Medicine at East Carolina University
Medical Director
Children's Hospital University Health Systems of Eastern Carolina
Greenville, North Carolina

Steven A. Santanello, DO

Medical Director
Trauma Services
Grant Medical Center
Columbus, Ohio

Eric Savitsky, MD

Assistant Professor of Medicine
Emergency Medicine/Pediatric Emergency Medicine
UCLA Emergency Medicine Residency Program
Los Angeles, California

Perry W. Stafford, MD, FACS, FAAP, FCCM

Chief of Trauma and Surgical Critical Care
Associate Professor of Pediatric Surgery
Department of Pediatric General and Thoracic Surgery
Children's Hospital of Philadelphia, PA.

© 2004 Thomson American Health Consultants
All rights reserved

Incidence of Missed Injuries

Many trauma centers track missed injuries as a quality improvement measure. Despite this, determining the true incidence of missed injuries is difficult for several reasons. The definition of a missed injury or delayed diagnosis varies from series to series. Most published series are retrospective reviews, which may estimate incorrectly the true incidence of missed injuries. Many studies concentrate on a specific type of missed injury. Long-term follow-up of trauma patients often is not available, and a patient with a missed injury may seek treatment at another location. The true incidence of missed injuries also is underestimated when autopsies are not obtained after traumatic deaths. A series of trauma death autopsies showed a 34% rate of missed injuries, 5% of which were the cause of death.⁵ The incidence of missed injuries in retrospective studies has been described as 1-9%. (See Table 1.) Enderson et al found that the incidence increased from a 2% missed

injury rate when studied retrospectively to a 9% rate when studied prospectively at the same institution.² A prospective study from Janjua et al described a rate of missed injuries as high as 14.5%. A smaller study from Australia reported 309 missed injuries in 798 patients (34%).⁶ Although two authors reported delayed diagnoses that resulted in potentially preventable deaths, the prospective literature suggests that few of these missed injuries result in death or significant disability.^{2,6,7} The true incidence of missed injuries is not defined, but delays in diagnosis clearly are an ongoing problem in centers treating injured patients. While a certain number of missed injuries will remain unavoidable, the challenge to ED physicians is to develop strategies to minimize missed injuries within a trauma system.

Legal Implications of Missed Injuries

Many lawsuits arise as a result of traumatic injuries, most of which are directed at the person responsible for the injury. In an increasingly litigious society, many physicians fear that caring for injured patients may place them at risk for involvement in a malpractice lawsuit. In fact, fear of lawsuits was cited in a study of why surgeons chose to not be involved in the care of trauma patients. The actual incidence of trauma malpractice suits has not been well described. A review of malpractice cases involving Illinois radiologists showed that missed diagnoses accounted for the largest group of malpractice cases, and that almost 20% involved trauma patients.⁸ Although there is clearly medicolegal risk associated with treating trauma patients for many reasons, perhaps the best defense is participation in a system for trauma care. Weiland et al reviewed the incidence of trauma malpractice claims in Arizona and found that only 22% were filed against Level I trauma centers and the remaining 88% were filed against non Level I trauma centers and/or outpatient centers.⁹ They concluded that the organized system of evaluation and treatment mandated at Level I trauma centers may lead to less malpractice exposure and lower malpractice costs.

Nontrauma centers may consider implementation of a standardized trauma care system in conjunction with local surgical support. Policy development that focuses on a relationship with a trauma center and a continuum of care facilitates continuous quality improvement between the facilities and maximizes utilization of both parties' resources.

Factors Contributing to Missed Injuries

Altered Levels of Consciousness. Several studies have emphasized the role of altered levels of consciousness in contributing to missed injuries. Patients with a decreased level of consciousness or head injury, patients who have been sedated or intubated, or those with drug or alcohol intoxication may be unable to give a history of the trauma or provide a detailed medical history. In addition, they may be unable to cooperate with the physical exam and may be

*Trauma Reports*TM (ISSN 1531-1082) is published bimonthly by Thomson American Health Consultants, 3525 Piedmont Road, N.E., Six Piedmont Center, Suite 400, Atlanta, GA 30305. Telephone: (800) 688-2421 or (404) 262-7436.

Vice President/Group Publisher: Brenda Mooney

Editorial Group Head: Valerie Loner

Managing Editor: Allison Mechem

Marketing Manager: Schandale Kornegay

Periodicals postage paid at Atlanta, GA.
(GST registration number R128870672.)

POSTMASTER: Send address changes to *Trauma Reports*, P.O. Box 740059, Atlanta, GA 30374. Copyright © 2004 by Thomson American Health Consultants, Atlanta, GA. All rights reserved. Reproduction, distribution, or translation without express written permission is strictly prohibited.

Accreditation

*Trauma Reports*TM continuing education materials are sponsored and supervised by Thomson American Health Consultants. Thomson American Health Consultants designates this continuing education activity for up to 2.5 hours in Category 1 credit toward the AMA Physician's Recognition Award. Each physician should claim only those hours of credit that he/she actually spent in the educational activity. This CME activity was planned and produced in accordance with the ACCME Essentials. Approved by the American College of Emergency Physicians for 2.5 hours of CEP Category 1 credit.

Thomson American Health Consultants (AHC) is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

Trauma Reports[®] is approved for approximately 2.5 nursing contact hours. This offering is sponsored by Thomson American Health Consultants, which is accredited as a provider of continuing education in nursing by the American Nurses' Credentialing Center's Commission on Accreditation. Provider approved by the California Board of Registered Nursing, Provider Number CEP 10864, for approximately

THOMSON

**AMERICAN HEALTH
CONSULTANTS**

Conflict of Interest Disclosure

In order to reveal any potential bias in this publication, and in accordance with Accreditation Council for Continuing Medical Education guidelines, Drs. Dietrich (editor in chief), Bowman, Diebel, Falcone, Hanlon, Jones, Mahadevan, Perkin, Santanello, Savitsky, and Stafford (editorial board members), Corpron (author), and Winograd (peer reviewer) report no relationships with companies related to the field of study covered by this CE/CME program.

Subscriber Information

Customer Service: 1-800-688-2421

Customer Service E-Mail: customerservice@thomson.com

Editorial E-Mail: allison.mechem@thomson.com

World Wide Web page: <http://www.ahpub.com>

Subscription Prices

FREE to subscribers of *Emergency Medicine Reports*, *Pediatric Emergency Medicine Reports*, *Emergency Medicine Alert*, and *ED Management*.

For nonsubscribers, the price is \$239.

U.S. possessions and Canada, add \$30 plus applicable GST. Other international orders, add \$30.

Back issues: \$80. One to nine additional copies, \$279 each; 10-20 additional copies, \$209 each.

2.5 contact hours. This program (#0105-1) has been approved by an AACN Certification Corp.-approved provider (#10852) under established AACN Certification Corp. guidelines for 2.5 contact hours, CERP Category A.

This is an educational publication designed to present scientific information and opinion to health professionals, to stimulate thought, and further investigation. It does not provide advice regarding medical diagnosis or treatment for any individual case. It is not intended for use by the layman. Opinions expressed are not necessarily those of this publication. Mention of products or services does not constitute endorsement. Clinical, legal, tax, and other comments are offered for general guidance only; professional counsel should be sought for specific situations.

The intended audience for this publication is emergency, family, osteopathic, and general practice physicians and nurses who have contact with trauma patients.

This continuing education activity expires March 31, 2004.

For Customer Service,

Please call our customer service department at (800) 688-2421. For editorial questions or comments, please contact Allison Mechem, Managing Editor, at allison.mechem@thomson.com.

Table 1. Incidence of Missed Injuries and Delayed Diagnoses of Traumatic Injuries

AUTHOR	YEAR PUBLISHED	PATIENTS	MISSED INJURIES	MISSED INJURIES (%)
Retrospective reviews				
• Connors ¹¹ (pediatric)	2001	5549	58	1
• Houshian ¹²	2001	876	64	8.1
• Buduham ¹³	2000	567	46	8.1
• Furnival ¹⁴ (pediatric)	1996	1175	53	4.3
• Rizoli ¹⁰	1994	876	64	8.1
• Hirshberg ⁴	1994	41,200	117	0.2
• Chan ¹⁵	1986	327	39	38
Prospective reviews				
• Enderson ²	1990	399	41	9
• Junjua ⁶	1998	206	134	65
• Vles ⁷	2003	3879	55	1.3

unable to localize pain or tenderness on exam. In a related issue, small children often represent diagnostic challenges because of difficulties obtaining a history and eliciting complaints of pain. Patients with any limitations of communication require a higher index of suspicion than the awake, adult patient. Interestingly, most series of pediatric patients actually show a lower rate of missed injuries, perhaps because of the heightened awareness of practitioners to the limitations of history and exam that can be obtained in pediatric patients. Many of the large studies of missed injuries have identified lower Glasgow Coma Scale scores, pharmacologic paralysis, and/or significant head injuries as factors predicting missed injuries.^{2,7,10} Any patient with a decreased level of consciousness should be evaluated with a high index of suspicion for injuries and should be continuously re-evaluated as his or her level of consciousness improves.

Misinterpretation of Studies and/or Inadequate Films. Frequently, ED physicians are confronted with radiographs that must be correlated with the clinical condition of the patient. The majority of EDs do not have continuous availability of attending radiologists for interpretation of diagnostic studies. Even between radiologists, discordant interpretations of radiographic studies occur. In one series of 512 trauma cases involving abdominal and pelvic computed tomography (CT) studies, 153 (29.9%) discordant readings occurred between radiologists, and patient care was changed in 12 (7.8%) of cases.¹⁶ If attending radiology staff is not available at the time of initial interpretation, films should be systematically reviewed with them at a later time.

In addition, films that do not provide adequate visualization of the injured area also may lead to misdiagnosis or delayed diagnosis.

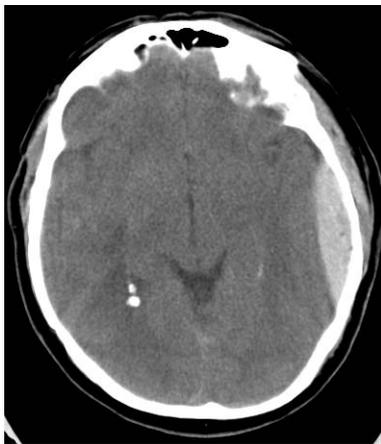
A review by Janjua et al showed that films that were more likely to be inadequate radiologic views included missing a joint above or below a suspected injury; chest

films that miss the clavicles, shoulders, or diaphragm; pelvic films that fail to show the femoral heads, and cervical spine films.⁶ Inadequate films may occur because of lack of patient cooperation or difficulties positioning patients. Films should be reviewed carefully with attending radiology staff to ensure adequate films before interpretation is completed, and alternative imaging strategies such as tomography may be required if positioning prevents adequate films.

Isolated System Injury. A review by Muckart and Thomson suggested that missed injuries could occur in patients admitted for an "isolated" injury to a non-trauma service.¹⁷ Inadequate histories, inadequate clinical assessments, and inappropriate index of suspicion may be due to inexperience in trauma care or premature direction of a patient to a subspecialty service. The objective evaluation of the contribution of these factors is difficult to quantify, but certainly exists in most settings. The easiest way to prevent these injuries is formal training in a trauma system such as ATLS, continued education in trauma by practitioners, on-going quality improvement at each center, careful supervision of less experienced members of the trauma team, and multi-disciplinary interactions that involve all subspecialty services.

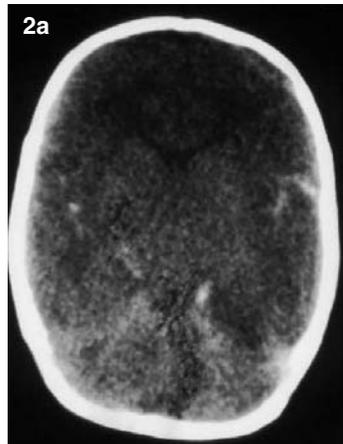
Hemodynamic Instability/Life-threatening Injury. Not surprisingly, patients with hemodynamic instability and life-threatening injuries represented a significant number of delayed diagnoses in many series. The need for aggressive resuscitation and early operative intervention delayed performance of the secondary survey and may lead to diagnostic delays. Scalea et al reviewed injuries missed at initial operation in patients with penetrating trauma.¹⁸ They found that all but one of these patients presented in shock and required emergency evaluation and operation. Hypothermia and coagulopathy preventing complete operative evaluation occurred in many of these patients. If at all possible, an early secondary survey should be performed

Figure 1. Epidural Hematoma



CT scan of a child who fell from a bicycle and who has a Glasgow coma score of 15 and protracted emesis.

Figures 2a and 2 b. The Spectrum of Abusive Head Trauma



2a. CT scan of a child with a diffuse axonal injury (cerebral edema, subarachnoid blood). **2b.** A CT scan of child showing a chronic, left-sided, subdural hematoma.

before the patient is taken to the operating room, since evaluation often can be continued in the operating room; however, if delayed, a comprehensive physical exam with appropriate imaging should be performed as soon as the patient is stable. Special consideration should be given to not missing a second life-threatening injury, especially maintaining spinal precautions to prevent spinal cord injury in patients being taken to the operating room. Also important is evaluating the severely head-injured patient or the patient with orthopedic injuries for abdominal injuries before proceeding to the operating room. This most often can be done quickly with a diagnostic peritoneal lavage, which can even be done while other operative procedures are being performed.

Late Presentation. Some injuries are prone to late presentation rather than late diagnosis. Most common of these is a contusion or injury to the bowel that initially is not full thickness or associated with perforation, but later progresses to a full thickness injury and peritonitis. These injuries may be associated with initially normal CT scans. While delay of treatment of an intra-abdominal perforation may not be associated with increased morbidity in some (especially the pediatric) populations,¹⁹ other authors have reported increased morbidity and mortality with delays.²⁰ Any patient with significant abdominal pain and a normal CT should be carefully and sequentially examined to prevent a delay in diagnosis.²¹

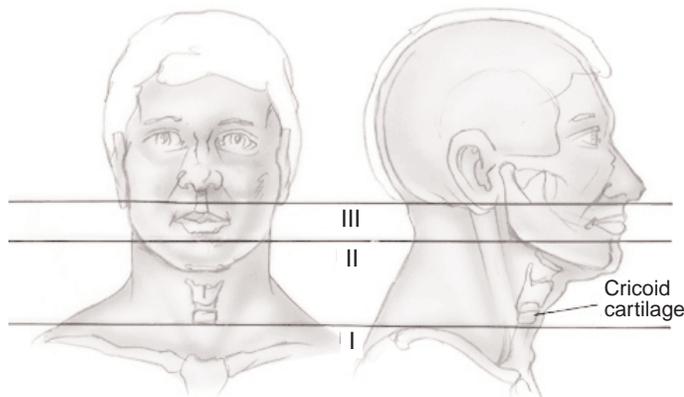
Lack of Repeat Exams. The failure to conduct serial physical examinations as the patient's condition changes frequently has been cited as a reason for missed injuries and is the focus of many trauma centers' goals for quality improvement. The concept of a "tertiary survey" is an attempt to minimize this factor and is discussed at length below.²

Prevention of Missed Injuries by Site

Head Injuries. Many studies have focused on the issue of missed intra-cranial or brain injuries. With the advent of widely available CT, it is a frequent diagnostic adjunct for patients with any type of head injury or multisystem trauma. Secondary to the easy accessibility of this modality, guidelines have been suggested to determine what patients require CT scanning and which patients may be clinically cleared without the use of this diagnostic modality. Low-risk patients are asymptomatic or have minimal symptoms. It should be remembered that in pediatric patients, a number of children with an epidural hematoma will present with a Glasgow coma score of 15 and a paucity of clinical findings. (See Figure 1.) Moderate-risk patients are those who have an unreliable history, change in consciousness, post-traumatic seizures, vomiting, or amnesia, and those with multiple trauma or skull fractures. High-risk patients are those with depressed or decreasing levels of consciousness, penetrating injuries, depressed skull fractures, and those with focal neurologic signs. Patients in the moderate or high-risk groups should undergo CT scanning to rule out an intra-cranial injury. Teasdale et al demonstrated that the mortality rate from extra-axial hematomas was reduced by 25% by the liberal use of CT scans.²² (See Figure 1.) There still is some controversy regarding the utility of skull radiography in the evaluation of closed head injuries; however, the widespread use of CT scanning for patients with any significant symptoms of head injury has led to a marked decrease in the need for routine skull films.

Several studies have suggested that abusive head trauma may be difficult for physicians to recognize. Frequently, infants and toddlers with abusive head trauma present with nonspecific symptoms such as vomiting, irritability,

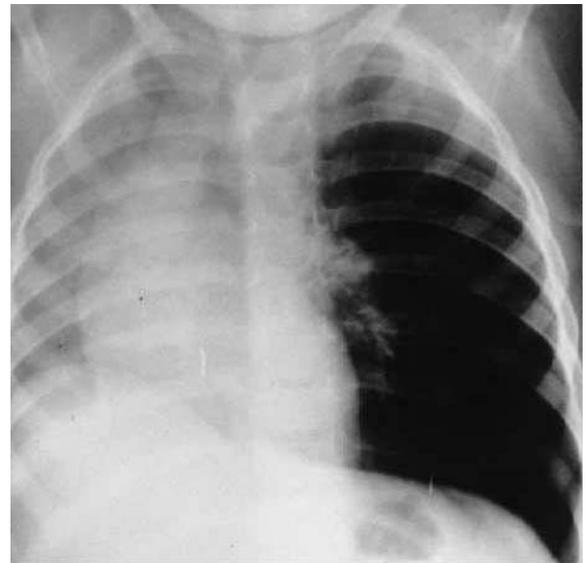
Figure 3. Zones of the Neck



Zone I extends from the clavicle to the cricoid cartilage, Zone II from the cricoid cartilage to the angle of the mandible, and Zone III from the angle of the mandible to the base of the skull.

Used with permission from: Brohi K. Penetrating neck injury. *Trauma.org* 2002;7:6. Accessed online (12/7/2003) at www.trauma.org/vascular/neckvasc.html.

Figure 4. Pneumothorax



A pediatric trauma patient with a tension pneumothorax.

and lethargy, and when the caretaker omits a history of trauma, an abusive head injury mistakenly may be diagnosed as a less serious condition. Carole et al studied 173 cases of abusive head trauma in children younger than 3 years of age. All of the children had a serious head injury, and 31% had been seen previously by physicians who did not make the diagnosis. Suggestions to facilitate the diagnosis of abusive head trauma include: 1) Carefully examining the child for facial/scalp abrasions or bruises; 2) considering the diagnosis of abusive head trauma in infants or children with vomiting or irritability; and 3) liberally using radiologists to interpret x-rays and head CTs in cases of suspected child abuse.²³ (See Figures 2a and 2b.) Although often dramatic in appearance, facial injuries seldom are life-threatening and may be missed while associated injuries are evaluated and treated. The identification of impending airway obstruction with multiple mandibular fractures or with combined maxillary, mandibular, and nasal fractures always must be a priority in assessing facial fractures. Any patient with significant facial trauma requires an evaluation for associated brain injury, skull fractures, and cervical spine injuries. Identification of facial fractures requires a high index of suspicion and a careful physical exam, including careful palpation and a complete motor/neurologic examination. Imaging for suspected facial injuries may require axial and coronal CT scans. Panoramic x-rays of the mandible can be helpful in identifying mandibular fractures.

Penetrating Neck Injuries. Penetrating neck injuries require a rapid, accurate assessment of potentially life-threatening injuries that may be associated with the zone of injury. An adequate airway must be assured, and if there is

any question of airway compromise, endotracheal intubation or a surgical airway is indicated. For the purpose of evaluation of penetrating neck injuries, the neck is divided into three anatomic zones. Zone I extends from the clavicle to the cricoid cartilage, Zone II from the cricoid cartilage to the angle of the mandible, and Zone III from the angle of the mandible to the base of the skull. (See Figure 3.) Injuries to Zone I and Zone III usually require radiologic evaluation for co-existing injuries because of the difficulties examining and operatively exposing these areas. Clinical findings that suggest a significant Zone II injury include active external bleeding from the wound, a neck bruit or thrill, dysphagia, hoarseness, subcutaneous emphysema, a large or expanding hematoma, oropharyngeal bleeding, a “sucking” neck wound, or a neurologic defect. These findings suggest the need for early operative intervention. The diagnostic work-up for an asymptomatic Zone II injury is controversial. One school of thought is mandatory operative intervention for any Zone II injury that penetrates the platysma. The philosophy of selective management advocates pan-endoscopy (laryngoscopy/tracheoscopy/bronchoscopy/esophagoscopy), esophagography and arteriography or duplex scanning. A prospective study by Golueke et al showed that there was no difference in length of stay, morbidity, or mortality between mandatory operative exploration and selective management.²⁴ Another study showed a 5% rate of missed injuries even in patients who had operative exploration.²⁵ The choice of an operative approach vs. a more selective approach should be dictated by available resources to rapidly complete the evaluation. There is significant morbidity and mortality associated with both vascular and esophageal injuries in this setting.

Figure 5. Diaphragmatic Injury



A patient with a lower lobe opacification and an underlying diaphragmatic injury.

Table 2. Radiographic Signs of Thoracic Great Vessel Injury

- Sternal, scapular, or 1st or 2nd rib fracture; multiple rib fractures
- Loss of aortic knob contour
- Widened mediastinum (greater than 8 cm)
- Left mainstem bronchus depressed
- Loss of perivertebral pleural stripe
- Calcium deposition in wall of aortic knob
- Anterior displacement of trachea on lateral film
- Loss of aortic-pulmonary window on lateral film
- Deviation of nasogastric tube
- Lateral displacement of trachea
- Apical hematoma (“cap”)

Table 3. Factors to Consider When Evaluating for Intra-abdominal Injury after MVA*

- Position in vehicle (driver or passenger)
- Restraint status and type of restraint
- Speed and type of impact
- Damage to vehicle
- Need for prolonged extraction
- Status of other victims
- Patient’s level of consciousness
- Hemodynamic stability during transport
- Other distracting injuries
- Age of patient

* MVA = motor vehicle accident

Thoracic duct injuries are rare, but may be associated with a left subclavian or internal jugular injury. These may be recognized only when the patient develops a transcutaneous fistula with fluid output that has elevated triglycerides, high protein and fat content, and lymphatic predominance on a white blood cell count. These usually can be treated with non-operative management.

Thoracic Injuries. There are many challenges in the diagnosis of intra-thoracic injuries. Life-threatening injuries that may be missed on initial evaluation include tension pneumothorax, pericardial tamponade, and rupture of intra-thoracic great vessels. Hirshberg et al found two missed tension pneumothoraces in 234 patients with penetrating chest trauma.⁴ Tension pneumothoraces may be diagnosed by tracheal shift or decreased breath sounds, although both of these findings can be difficult to evaluate in a noisy trauma room. (See Figure 4.) Chest tube placement is required after any placement of an angiocatheter to relieve a suspected pneumothorax either in the field or in the trauma room.

Aortic transection accounts for 16% of motor vehicle accident fatalities. Radiographic findings on a chest film that suggest thoracic aorta injury are described in Table 2. These findings should dictate rapid evaluation with either angiography or helical CT scanning to rule out an aortic injury.

Bronchial fractures are found only in 1.5% of patients with major chest trauma. More than 30% of bronchial fractures are initially missed, and almost 50% are delayed diagnoses. Approximately 80% occur within 2.5 cm of the carina. Detection of this injury requires vigilance and awareness of the indirect “P” signs — persistent, progressive pneumomediastinum and/or pneumothorax (especially if the pneumothorax is unrelieved by chest tube drainage). The fallen lung sign is specific but uncommon. Bronchoscopy is recommended for evaluation of bronchial injuries.

Diaphragmatic Injuries. Injuries secondary to penetrating wounds equally are divided between the left and right hemidiaphragms; blunt rupture is most often on the left (75%) side. Bilateral rupture is rare (2%). Recognizing diaphragm injuries is especially difficult when a penetrating chest injury is not realized to extend to the diaphragm. A diagnosis of diaphragmatic injury on chest radiograph is suggested by obstruction of the left cardiophrenic angle, elevation of the left hemidiaphragm, and herniation of the stomach or colon through an injury in the postero-lateral diaphragm. (See Figure 5.) Diaphragmatic rupture can be mimicked by atelectasis, hemothorax, pneumothorax, gastric dilatation, pulmonary contusion, intra-abdominal fluid, traumatic pneumatocele, or congenital eventration. A right-sided

Figure 6. Seatbelt Mark



rupture can be easy to miss because the liver blocks the herniation of abdominal contents into the chest. These injuries can be missed even on CT scanning. Contrast studies including upper gastrointestinal series, and barium enema and magnetic resonance imaging may be helpful in some settings. Other diagnostic modalities include laparoscopy and thoracoscopy. Medial injuries near the esophageal hiatus can be missed even on operative exploration. Late presentation of diaphragmatic injuries is not uncommon and can occur in the difficult setting of a patient whose abdominal contents have herniated through the defect. Repair of these injuries can be very difficult and require abdominal, thoracic, or thoraco-abdominal approaches.

Intra-abdominal Injuries. One of the leading causes of preventable trauma deaths is the missed or delayed diagnosis of intra-abdominal injuries. Blunt trauma is the most common mechanism of abdominal injury, and motor vehicle crashes account for approximately 75% of blunt injuries to the abdomen. Several mechanisms can cause intra-abdominal injury in the setting of blunt trauma; sudden increases in intra-abdominal pressure can cause rupture of a hollow viscus or injury to solid organs, deceleration injuries can lead to shearing solid organ and vascular injuries, and solid and hollow organs directly can be compressed between an outside force and the spinal column (i.e., seat belt injuries). (See Figure 6.) Intra-abdominal injuries can be very difficult to diagnosis in the immediate post-injury period because intra-abdominal bleeding does not present with clear symptoms, especially in pediatric patients. (See Table 3.) It is prudent to assume that any patient who has sustained significant blunt force injury may have an intra-abdominal injury. The optimal diagnostic modalities to diagnoses intra-abdominal injury vary by

Figures 7a and 7b. Intra-abdominal Injuries



Figure 7a. A liver laceration. Figure 7b. A splenic fracture in a child with a bicycle handlebar injury.

trauma center and include combinations of CT scanning (see Figures 7a and 7b), ultrasound, and peritoneal lavage. There is significant controversy regarding the optimal imaging in any given setting for blunt or abdominal trauma, but perhaps the best guideline is to use the modality that can be done quickly and interpreted most accurately by each facility. A finding on CT scan or ultrasound imaging never should change the need in the operating room for a systematic search for any intra-abdominal injury. This evaluation includes the need for careful exposure and examination of the esophagus, diaphragm, stomach, small bowel, colon, pancreas, spleen, liver, kidneys, vessels, and retroperitoneum. This systematic evaluation is even more important in abdominal penetrating trauma.

The optimal evaluation of stab wounds to the abdomen first requires a local wound exploration. If the peritoneum has not been entered, the patient does not require exploration. It is important to remember that the anterior extent of the abdominal cavity is from the fourth to the fifth intercostal space to the pubis, and the posterior extent is from the

Figure 8. Subtle Tibial Spiral Fracture



tip of the scapula to the sacrum. Posterior stab wounds should be evaluated by CT scanning and anterior ones by diagnostic peritoneal lavage or CT scanning. Findings of intraperitoneal and/or retroperitoneal fluid or air suggest the need for operative exploration.

Extremity Fractures. Musculoskeletal injuries are the most commonly missed injuries.^{4,7,14} (See Table 4.) Extremity fractures represented up to 50% of delayed diagnoses in several series. Physical exam findings of fractures include pain and tenderness, limitations of mobility, loss of function, swelling, crepitus, and deformity. During initial examination and resuscitation, these findings may be subtle. Non-displaced fractures in patients with other distracting injuries often are not diagnosed for several hours until pain control of other injuries is improved and swelling is more apparent. (See Figure 8.) The most common reason to miss a fracture is failure to obtain imaging studies. A related reason that musculoskeletal injuries are missed is that the area of a deformity is imaged but contiguous parts of the body (proximal and distal to the fracture) are not imaged. (See Table 5.) Many missed musculoskeletal injuries occur in patients who present with a decreased level of consciousness, are intubated, or present with life-threatening injuries. Often fractures are identified when a patient's mental status improves or after a patient is extubated, allowing him or her to describe pain at a fracture site.

Table 4. Errors in Radiographic Interpretation

	DISLOCATIONS	OCCULT FX	HALF OF INJURIES
MISSED			
Wrist	Scapholunate DS	Scaphoid	Galeazzi
	Perilunate DL and lunate DL	Triquetrum	Distal radius FX + carpal injury
Elbow	Radial head DL	Radial head	Monteggia
Pelvis/hip	Hip DL	Femoral neck	Another ring FX
		Sacrum	
		Acetabulum	
Knee	Knee DL	Tibial plateau	Maisonneuve
		Segond	
		Patella	
Foot	Lisfranc injury	Calcaneus	Thoracolumbar + calcaneus FX
		Talus	

Key: FX = fracture; DS = dissociation; DL = dislocation

Adapted from: Lin M. Pitfalls in orthopedic radiographic interpretation. General Session, Mediterranean Emergency Medicine Congress. Barcelona, Spain; Sept. 15, 2003.

Vascular Trauma. Vascular injuries may be associated with musculoskeletal injuries. (See Table 6.) The classic findings of peripheral arterial injury (external bleeding, expanding hematoma, murmur, thrill, pulselessness, or ischemia) may justify operative exploration without further studies. Softer findings of proximity, nonexpanding hematoma, or history of bleeding at a site may require further evaluation. Duplex ultrasound can be very sensitive for occlusion, intimal flaps, arteriovenous fistulas, and pseudoaneurysms, but arteriography remains the gold standard for diagnosing vascular injuries.

Compartment Syndrome. Compartment syndrome is a risk after many significant extremity injuries. Compartment syndrome occurs when elevated pressure within a closed osseofascial compartment results in microvascular compromise and eventually causes muscle and nerve ischemia and necrosis. The consequences may include loss of function, gangrene, limb loss, and development of myoglobinuria leading to renal failure. Clinicians especially should be alert to the development of compartment syndrome in patients with high-energy injuries, crush injuries, or with fractures associated with large, soft-tissue injuries. The classic complaint of a patient with early compartment syndrome is pain out of proportion to the injury. The pain usually is unaffected by splinting or positioning. Tingling and/or numbness also can occur. The earliest finding on examination is a tense, swollen extremity that is tender to palpation. There may be pain with passive extension of involved muscles. Arterial pulses and capillary refill may be normal until late in the course of the injury. Diagnosis of compartment syndrome can be confirmed with measurement of compartment pressures. This easily may be per-

Table 5. Commonly Associated Fractures

Calcaneal fractures	→	Thoracolumbar fractures
Posterior fracture/ dislocation of the hip	→	Femoral fractures or severe tibia/fibula fractures
Transverse fracture of 5th lumbar vertebrae	→	Sacral fracture

Table 6. Vascular Injuries Associated with Musculoskeletal Injuries

FRACTURE	→	VASCULAR INJURY
Posterior knee dislocation	→	Popliteal vessel disruption
1st and 2nd rib fractures, sternal fractures, scapula fractures	→	Thoracic aortic injury
Supracondylar humeral fracture	→	Brachial artery injury

formed using a Stryker STIC (Stryker Corp., Kalamazoo, MI) catheter or other apparatus. Compartment pressure measurements should be performed on any patient with signs and symptoms of compartment syndrome or on any patient with an unreliable exam due to an altered level of consciousness and who has a significant extremity injury. It should be remembered that a single measurement may not predict development of compartment syndrome, and that sequential measurements and multiple measurements in each compartment are required. The pressure threshold at which a fasciotomy is indicated is somewhat debated, but most authors recommend that decompression should be performed if a compartment syndrome exceeds 40 mmHg or if the compartment pressure is within 30 mmHg of the patient's diastolic pressure.

Spinal Injuries. One of the most feared missed injuries in trauma is the missed spinal fracture. Some studies of spinal trauma have recorded a missed injury rate as high as 33%. Most frequently, a delayed or missed diagnosis is attributed to failure to suspect an injury to the cervical spine, inadequate radiographs, or incorrect interpretation of radiographs. (See Figure 9.) Many studies have suggested that in an awake, alert, cooperative adult patient without distracting injuries, a lack of tenderness, lack of pain, and a normal physical exam eliminate the need for extensive imaging of the cervical spine. In patients who do not meet these criteria, the evaluation is less clear. The standard three-view, plain radiographic film series is the lateral, anteroposterior, and open-mouth view. The lateral view alone is inadequate and will miss approximately 15% of cervical spine injuries. If the lower portion of the cervical spine is not clearly visualized, a CT scan of the region is

Figure 9. C-spine Fracture

Lateral cervical spine radiograph in a pediatric trauma patient demonstrating the ability of tubing to potentially obscure injuries.

indicated. The addition of two oblique views has not been shown to increase the sensitivity of plain film evaluation. More subtle ligamentous and soft tissue injuries may require CT scanning, flexion extension views, (See Figure 10) or magnetic resonance imaging for adequate evaluation. The safest approach is to maintain spinal immobilization until the patient can be evaluated completely, including with an adequate physical exam. The thoracolumbar spine, although more protected, is at risk in major trauma and should be assessed both clinically and radiographically. Any patient with a neurologic defect should remain immobilized, intravenous high-dose steroids should be initiated, and magnetic resonance imaging should be obtained. Any patient with back pain and/or tenderness should be evaluated for thoracic and lumbar fractures, and patients with spinal fractures at any level should have radiologic examination of the entire spine because of the incidence of associated fractures.

Tertiary Exam

The tertiary exam was first introduced in 1993 by Ender-son et al to assist with the diagnosis of any injuries that were not identified during the primary and secondary survey.² The tertiary survey involved repetition of the primary and secondary surveys, meticulous physical examination, repetition of the history of the trauma history, and review of all laboratory and radiographic studies. These authors' use of this tertiary survey resulting in diagnosis of missed injuries in 36 of 399 patients (9%). The most common reason for injuries to be missed was altered level of consciousness. None of the missed injuries resulted in death, but one missed injury resulted in disability and seven required operative intervention. In a second large series, a tertiary trauma

Figure 10. Cervical Spine Injury



C₆₋₇ ligamentous injury in a trauma patient.

survey detected 56% of the injuries missed during the initial assessment within 24 hours of admission.⁶

Conclusion

Missed injuries and delays in diagnosis remain a concern for clinicians caring for trauma patients. Systematic evaluation, such as that dictated by ATLS, careful review of imaging studies, knowledge of patterns of injury, and sequential exams including tertiary surveys can help to decrease the number of missed injuries. The tracking of missed injuries and continued evolution of strategies to decrease missed injuries and delays in diagnosis should be part of every facility's quality improvement agenda. Adherence to established standards such as the primary and secondary surveys mandated by ATLS and the suggestion of tertiary surveys will provide the best patient care and the best defense.

References

1. American College of Surgeons Committee on Trauma. Resources for the optimal care of the injured patients. Chicago: American College of Surgeons; 1999.
2. Enderson BL, Reath DB, Meadors J, et al. The tertiary trauma survey: A prospective study of missed injury. *J Trauma* 1990; 30:666-669.

3. Hoyt DB, Hollingsworth-Fridlund P, Fortlage D, et al. An evaluation of provider-related and disease-related morbidity in a level I university trauma service: Directions for quality improvement. *J Trauma* 1992;33:586-601.
4. Hirshberg A, Wall MJ, Allen MK, et al. Causes and patterns of missed injuries in trauma. *Am J Surg* 1994;168:299-303.
5. Albrektsen SB, Thomsen JL. Detection of injuries in traumatic deaths: The significance of medico-legal autopsy. *Forensic Sci Int* 1989;42:135-143.
6. Janjua KJ, Sugrue M, Deane SA. Prospective evaluation of early missed injuries and the role of tertiary trauma survey. *J Trauma* 1998;44:1000-1007.
7. Vles WJ, Veen EJ, Roukema JA, et al. Consequences of delayed diagnosis in trauma patients: A prospective study. *J Amer Coll Surg* 2003;197:596-601.
8. Berlin L. Malpractice and radiologists, update 1986: An 11.5 year perspective. *AJR Am J Roentgenol* 1986;147:1291-1295.
9. Weiland DE, Malone JM, Krebs R, et al. Trauma malpractice claims related to trauma level designation. *Am J Surg* 1989;158: 553-559.
10. Rizoli SB, Boulanger BR, McLellan BA, et al. Injuries missed during initial assessment of blunt trauma patients. *Accid Anal Prev* 1994;26:681-686.
11. Connors JM, Ruddy RM, McCall J, et al. Delayed diagnosis in pediatric blunt trauma. *Ped Emerg Care* 2001;17:1-4.
12. Houshian S, Larsen MS, Holm C. Missed injuries in a level I trauma center. *J Trauma* 2002;52:715-719.
13. Buduhan G, McRitchie DI. Missed injuries in patients with multiple trauma. *J Trauma* 2000;49:600-605.
14. Furnival RA, Woodward GA, Schunk JE. Delayed diagnosis of injury in pediatric trauma. *Pediatrics* 1996;98:56-62.
15. Chan RNW, Ainscow FRCS, Sikorski JM. Diagnostic failures in the multiple injured. *J Trauma* 1980;20:684-687.
16. Yoon LS, Haims AH, Brink JA, et al. Evaluation of an emergency radiology quality assurance program at a Level I trauma center: Abdomen and pelvic CT studies. *Radiology* 2002;224: 42-46.
17. Muckart D, Thomson S. Undetected injuries: A preventable cause of increased morbidity and mortality. *Am J Surg* 1991; 162:457-460.
18. Scalea TM, Phillips TF, Goldstein AS, et al. Injuries missed at operation: Nemesis of the trauma surgeon. *J Trauma* 1988;28: 962-966.
19. Bensard D, Beaver B, Besner, et al. Small bowel injury in children sustaining blunt abdominal injury: Is delayed diagnosis important? *J Trauma* 1996;41:476-483.
20. Flint LM, Viatle GC, Richardson JD, et al. The injured colon: Relationships of management to complications. *Ann Surg* 1981; 193:619-624.
21. Canty TG, Canty TG Jr, Brown C. Injuries of the gastrointestinal tract from blunt trauma in children: A 12-year experience at a designated pediatric trauma center. *J Trauma* 1999;46:234-240.
22. Teasdale G, Galbraith S, Murray, et al. Management of traumatic intracranial hematomas. *Br J Med* 1982;285:1695-1699.
23. Carole J, Hymel KP, Ritzen A, et al. Analysis of missed cases of

abusive head trauma. *JAMA* 1999;281:621-626.

24. Golueke PJ, Goldstein AS, Scalfani SJA, et al. Routine versus selective exploration of penetrating neck injuries: A randomized prospective study. *J Trauma* 1984;24:1010-1016.
25. Wood J, Fabian TC, Magiante EC. Penetrating neck injuries: Recommendation for selective management. *J Trauma* 1989; 26:602-607.

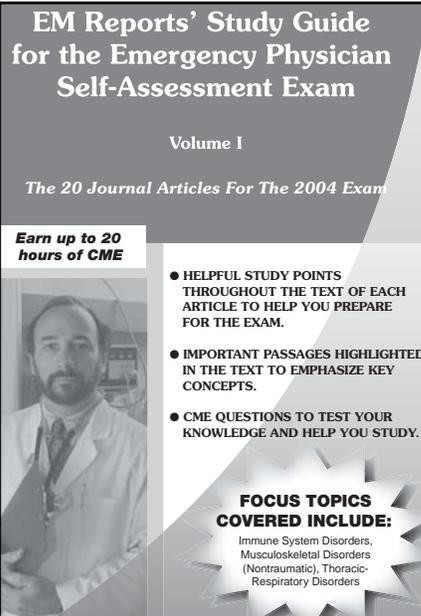
CE/CME Questions

1. Penetrating Zone II neck injuries:
 - A. can be safely observed if there is no expanding hematoma.
 - B. can be treated with operative exploration or pan-endoscopy, arteriography, and esophagraphy.
 - C. do not require exploration if there is penetration through the platysma muscle.
 - D. would include a stab wound just above the clavicle.
2. The purpose of the ATLS primary survey is to:
 - A. identify and treat immediately life-threatening injuries.
 - B. identify all injuries.
 - C. determine need for operative exploration.
 - D. determine the need for diagnostic imaging.
3. Presence of a calcaneal fracture should prompt evaluation of the:
 - A. proximal tibia.
 - B. distal femur.
 - C. thoraco-lumbar spine.
 - D. kidneys.
4. Posterior knee dislocations are associated with:
 - A. femur fractures.
 - B. hip dislocations.
 - C. injury to the popliteal vessels.
 - D. patellar fractures.
5. Tertiary surveys include:
 - A. comprehensive physical exam and history.
 - B. reviewing all imaging studies.
 - C. re-examination when the patient is not intoxicated.
 - D. All of the above

CE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you must complete the evaluation form provided and return it in the reply envelope provided to receive a certificate of completion.** When your evaluation is received, a certificate will be mailed to you.

EM Reports' Study Guide for the Emergency Physician Self-Assessment Exam



This convenient, all-in-one resource includes the full text of all 20 articles designated for the 2004 Life-long Learning and Self-Assessment (LLSA) exam. This useful book saves you from searching multiple web sites and journals. You save time because we've gathered all of the information for you.

We've also added several features to help streamline your study time. You'll benefit from:

- **Key study points**—conveniently located in the margins throughout each article, these points emphasize important concepts and help you to easily remember key information.

- **Important passages highlighted**—you'll be able to quickly hone in on essential concepts from each article with this useful feature.

- **Easy to handle study guide format**—designed with spiral binding so you can easily lay it flat for studying. All of the articles, study points, highlighted passages, and CME questions are included in this one convenient book that's portable.

- **Earn up to 20 CME credit hours**—earn valuable AMA Category 1 CME credits while you read.

Please reserve your copy now at the special prepublication rate of \$199—a better price than other study guides, plus enhanced study features!

Call now, 1-800-688-2421 or 404-262-5476 (please refer to prepublication discount code 82971). You also may order online at www.ahcpub.com.

8-1/2x11, 300+ pages, spiral bound, #S03170, prepublication discount price: \$199

THOMSON
AMERICAN HEALTH
CONSULTANTS

6. Factors contributing to missed injuries include:
 - A. patient education level.
 - B. patient intoxication with drugs or alcohol.
 - C. time between injury and presentation at the hospital.
 - D. time spent in the ED.

7. Aortic injury is suggested on chest radiograph by:
 - A. loss of aortic knob contour.
 - B. deviation of nasogastric tube.
 - C. apical "cap."
 - D. All of the above

8. A patient with multiple mandibular fractures requires immediate evaluation for:
 - A. cervical spine injury.
 - B. brain injury.
 - C. eye injury.
 - D. airway compromise.

9. Thoracic duct injuries:
 - A. commonly are associated with right subclavian artery injuries.
 - B. may present with a cutaneous, draining fistula.
 - C. always are present at the time of injury.
 - D. require immediate operative intervention.

10. Fracture of the transverse process of the 5th lumbar vertebrae often is associated with:
 - A. sigmoid colon injury.
 - B. bladder injuries.
 - C. iliac artery injury.
 - D. sacral fractures.

Answer Key:

- | | |
|------|-------|
| 1. B | 6. B |
| 2. A | 7. D |
| 3. C | 8. D |
| 4. C | 9. B |
| 5. D | 10. D |

Sourcebook Guides You Through Final EMTALA Rule

You and your facility waited more than a year for the final revisions to the Emergency Medical Treatment and Labor Act (EMTALA), but are they really good news?

ED managers and practitioners, hospital administrators, risk managers and others must quickly digest this complex regulation and determine how the changes will affect patient care.

EMTALA: The Essential Guide to Compliance from Thomson American Health Consultants, explains how the changes to EMTALA will affect emergency departments and off-campus clinics. In-depth articles, at-a-glance tables, and Q-and-As on real-life situations are presented, and key differences between the "old" EMTALA and the new changes are succinctly explained.

Here are some of the vital questions you must be able to answer to avoid violations and hefty fines:

* Do the revisions mean hospitals are less likely to be sued under EMTALA?

* How does EMTALA apply during a disaster?

* What are the new requirements for maintaining on-call lists?

* How does EMTALA apply to inpatients admitted through the ED?

* What are the rules concerning off-campus clinics?

Edited by **James R. Hubler, MD, JD, FACEP, FAAEM, FCLM**, Department of Emergency Medicine, OSF Saint Francis Hospital and University of Illinois College of Medicine, Peoria, and reviewed by **Kay Ball, RN, MSA, CNOR, FAAN**, Perioperative Consultant/Educator, K&D Medical, Lewis Center, OH, *EMTALA: The Essential Guide to Compliance* covers the EMTALA topics and questions that are most important to you, your staff, and your facility.

EMTALA: The Essential Guide to Compliance also provides 18 AMA Category I CME credits and 18 nursing contact hours.

Order your copy today for the special price of \$249! Call 1-800-688-2421 to receive this valuable guide to the new EMTALA.

CME Objectives

Upon completing this program, the participants will be able to:

- a.) Quickly recognize or increase index of suspicion for occult injuries;
- b.) Understand subtle findings that may signify underlying, serious trauma;
- c.) Understand various diagnostic modalities, their indications, and limitations for commonly missed injuries; and
- d.) Recognize both likely and rare complications that may occur as a result of missed diagnoses or delays in diagnosis.

In Future Issues:

Trauma Ultrasound