CHAPTER 72 ■ INITIAL MANAGEMENT OF THE TRAUMA PATIENT
SCOTT R. KARLAN • DANIEL R. MARGULIES

The many chapters of this book testify to the many facets of critical care. Most are applicable to trauma patients in the intensive care unit (ICU). In contrast, the initial management of the trauma patient requires a different focus and prioritization. This chapter presents common life-threatening problems that face all critical care physicians who care for trauma victims.

Trauma patients look different. Most start out younger and healthier than other ICU patients but the severity of many of their injuries mandates expert critical care management. How does initial trauma care differ from other critical care treatment? Time is the key. Many of the more common traumatic injuries are rapidly lethal. One’s desire to thoroughly evaluate a trauma patient must therefore be tempered by a need to prioritize within available time. This prioritization, aided by careful planning and a team approach, contributes to patient survival.

THE TEAM
Your treatment plan needs to start before the next trauma patient arrives. A multiply injured patient may require several simultaneous interventions. Having a team of physicians, nurses, technicians, therapists, and aides allows for parallel rather than sequential treatment. Adding personnel (e.g., x-ray technicians, respiratory therapists, surgical specialists) to your team encourages those individuals (and their departments) to commit to trauma care, potentially reducing treatment delays. Noise rises exponentially with the size of the team, making it difficult to communicate or to auscultate breath sounds and heart tones. Having a common paging system for all members of the team is essential to reduce redundancy and activate the necessary team prior to the arrival of the patient at your hospital. This activation system can be a tiered response depending on the facility you work in. Regardless, critically reviewing prior trauma resuscitations in your facility will reveal any needed additions or deletions of members to your team.

Take a lesson from the National Association for Stock Car Auto Racing (NASCAR). To function as a team, you need to practice as a team. Mock trauma drills allow you to do it over until you do it right. Do you have more than one chest tube set? How long does it take to get the drugs for a rapid sequence induction and intubation? Do you even have a pediatric endotracheal tube? A NASCAR team can change four tires and fill the gas tank in about a minute. Your team will need to establish IV access and administer fluid, gather baseline vital signs, and complete the primary survey in this time frame. Do team members understand the big picture (what needs to be done for the patient) beyond their specific assignments? Are they prepared to shift roles when necessary (e.g., when a patient needs intubation, or when IV access is problematic)? If you have team members trained in the medical intensive care unit, can they “think surgically,” as intervention may be needed without a clear diagnosis?

As you build a team, think outside the hospital. Organized trauma networks reduce preventable deaths (1,2). By joining such a network, your hospital integrates paramedics and other field triage personnel into your team. Although the number of trauma centers has risen from 471 in 1991 to 1,154 in 2002 (including 190 level I and 263 level II centers) (3), 46 million Americans still live more than an hour from a level 1 or 2 center (4). Dedicating the resources to become a level 1 or level II trauma center will optimize care at your hospital and in your community. These resources include on-site trauma surgeons, immediately available operating rooms, rapidly available surgical specialists, a trauma manager, quality improvement processes, and other benefits.

TRIAGE
Called to the scene of an accident, paramedics initially triage the victims. They determine who to transport and when and where to take them (following established community protocols). In all cases, the number of patients and severity of their injuries are weighed against available resources. Ideally the most severely injured are taken to the center most capable of treating that patient, so when many injuries occur at the same time they may be divided between available hospitals. Blunt and penetrating urban trauma typically involves relatively few patients at a time. Several simultaneous incidents may occur and may overwhelm a community. September 11 has taught us that we need to prepare for multiple victims.

In a mass casualty event, you may need to evacuate the emergency department (ED) to make room for incoming patients. The seriously injured will be brought in slowly as patients with minor injuries flood into your waiting room. ED physicians normally stay with the ED patients as they are moved elsewhere in the hospital. Although surgeons will be needed in the operating room, it is important that the vital role of making these initial triage decisions be filled by someone who is experienced in trauma management and understands the physiology of traumatic injury.

Triage is most effective at “ground zero,” a site in the field where patients are gathered prior to transport. If roads and communications are disrupted, much of the initial trauma care
may need to be provided at that site. Ideally, a physician with trauma experience and knowledge of community resources goes to the field to oversee triage rather than waiting in the emergency department.

Paramedics play a critical role even when triage is not an issue. Their observations may be the only medical history that is ever available. Did they speak to witnesses of a shooting? How far did a patient fall? Was extrication necessary after a car crash? How much blood was at the scene? Paramedics will communicate most of this information to the trauma team upon arrival, along with any other observations (patient stability, apparent injuries). Radio-communication provides much of this prehospital information, but direct communication with the paramedics before they leave is important. Knowing about likely injuries allows you to focus on treating the patient, rather than listening to paramedics, when the patient arrives. If paramedics have already started two large-bore IVs, intubated the patient, and given 2 liters of fluid, your priorities will change. Every minute of advance warning can save critical seconds later on.

PRIORITY

The American College of Surgeons, through its Advanced Trauma Life Support (ATLS) course (5), has taught genera-
tion of physicians and nurses to focus on the ABCDEs of trauma. “Airway, breathing, and circulation” is worth repeat-
ing over and over as you struggle to revive a trauma victim. When circumstances go from bad to worse (e.g., multiple si-
mots to the field to oversee injuries, in a deteriorating patient not responding to resuscitation), remember the ABCs. An ob-
structed airway is lethal within minutes. Securing an airway can buy you enough time to address many other injuries. For this reason, it is more important to look for airway obstruction (even in intubated patients) than for intracerebral bleeding, aortic dissection, pancreatic transection, or virtually any other injury.

After ensuring the ABCs, “D” is a reminder to consider disability or, more specifically, to perform a rapid neurologic examination. At the bare minimum, this should include an assess-
ment of the patient’s pupils (size and reaction to light), extremity motion (looking for lateralizing signs), and Glas-
gow coma scale. Assessing strength and sensation requires an awake, cooperative patient. In an unstable patient or patient with an altered mental status (from alcohol, drugs, or head trauma), you may need to complete the neurologic examination later that day or the following day. The Glasgow coma scale is primarily used as a tool for sequential assessment. Pa-
tients with head trauma or an altered mental status should be rescored every few hours. Their score should improve as they recover (or sober up), and given 2 liters of fluid, their priorities will change. Every minute of advance warning can save critical seconds later on.

THE PRIMARY SURVEY

ATLS divides the patient’s initial evaluation into a primary and secondary survey. The primary survey focuses on high-priority injuries: those that are rapidly lethal and rapidly correctable. Many common injuries are rapidly lethal. Rapidly correctable implies that you can fix (or temporize) the problem using simple tools (a laryngoscope, a chest tube, direct pressure, etc.) kept in an ambulance or in the ED. The primary survey is designed to identify such injuries (Table 72.1).

Airway Obstruction and Airway Management

Airway management is a common cause for anxiety. Failure in airway maintenance rapidly leads to death. Apart from the rare patient with severe facial trauma who requires an immediate cricothyrotomy, trauma patients should be approached in a standardized fashion. Assume that all patients are at risk for a respiratory arrest, and for a cervical spine injury, and are likely to have a full stomach.

Patients are categorized into three groups: (a) those who are awake, alert, and breathing with no difficulty at all; (b) those in respiratory distress who need immediate intuba-
tion; and (c) everyone else. The first group should be treated with periodic reassessment. With the second group, check for airway obstruction while setting up for a rapid sequence in-
duction and intubation. Simple measures, like a jaw thrust or

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<th>Table 72.1</th>
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<tr>
<th>Rapidly lethal and rapidly correctable injuries</th>
<th>Initial treatment</th>
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<tr>
<td>Airway obstruction</td>
<td>Obtain a secure airway</td>
</tr>
<tr>
<td>Tension pneumothorax</td>
<td>Needle thoracostomy</td>
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<td>Open pneumothorax</td>
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<td>Cardiac tamponade</td>
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<td>Peripheral arterial injuries</td>
<td>Direct pressure</td>
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P1: OSOOVY  P2: OSOOVY  QC: OSOOVY  T1: OSO
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ch in life, or an oral or nasal airway, rarely allow you to avoid intubation. However, these maneuvers may convert an emergent intubation into a semi-elective intubation. The third group includes all of the patients who don’t need intubation at that moment, but who may be close to needing it or who may need it in the future. This is the group that requires judgment. Trauma patients with an altered mental status but with no respiratory distress will be sent for a head CT scan. Some will stop breathing in radiology, a suboptimal place for an emergent intubation. If you try to intubate every patient prior to CT, you will fail 2% to 3% of the time (7). Failure to obtain an airway can be managed if you have a backup plan (8), including cricoid-bridge laryngoscopy. Generally, intubate patients with a Glasgow coma scale score of 8 or less. If a patient has no mental status changes but needs to go to the operating room, consider early intubation prior to transport, particularly if the patient has been hypotensive. If you have any doubt, err on the side of intubating the patient.

The best way to intubate a patient is the way that works best for you. Be consistent. Pick one set of drugs and your favorite Macintosh or Miller blade. If you develop a routine, you will be reminded to use suction and to apply cricoid pressure. Your success depends less on your speed and more on your skill with mask ventilation. Preoxygenation is critical. Several minutes of effective mask ventilation with 100% oxygen will create a luxurious amount of time to inspect the airway and place an endotracheal tube without disturbing the spine. Not every patient needs sedation. In an unresponsive patient, you can bypass the rapid sequence induction unless you have selected the drugs to reduce intracranial pressure during intubation.

Airway Management and the Cervical Spine

Any patient who rapidly decelerates (e.g., motor vehicle accident, fall) requires spinal stabilization. Such a patient should arrive on a backboard with a collar. Also consider spinal injuries after direct trauma to the head, neck, or back. Clearing the cervical spine requires more than a radiograph as ligamentous injuries can occur in the absence of radiologic findings. In an alert, cooperative patient who has no neck tenderness, no distracting injury, and a normal neurologic examination, the collar may be safely removed (9). Unfortunately, neck tenderness and mental status changes are common. In such patients, clearing the C-spine is not an immediate priority and should be delayed until they are stable. Clearance criteria are controversial and may require a C-spine series or CT of the neck, to rule out fractures, followed by flexion/extension views or magnetic resonance imaging (MRI) of the neck, to rule out ligamentous injuries.

Protecting the spine is occasionally at odds with needed intervention. This occurs most often during intubation, although there are other circumstances where it may be necessary to transiently remove the front of the collar. This conflict is best overcome by assigning one team member to maintain in-line stabilization (not traction) while other team members perform necessary interventions. Although direct laryngoscopy will an- gulate the spine despite in-line stabilization (10), orotracheal intubation can be performed safely in patients with cervical spine fractures when reasonable precautions are taken (11). Fiberoptic intubation can be done without any movement of the neck and should be considered in high-risk patients when time permits. While nasotracheal intubation also avoids spinal manipulation, it is rarely used in trauma because it requires an awake, breathing patient; takes time to perform; can cause nasal bleeding; and can lead to vomiting and aspiration.

Pneumothorax and Tension Pneumothorax

Pneumothorax is one of the most common thoracic injuries. As a consequence, any physician caring for trauma patients should be comfortable placing a chest tube. Air usually enters the pleural space from a lung injury, although it may also enter through a chest wound. During normal inspiration, the diaphragm contracts, intrapleural pressure falls, and the lung expands via the bellows effect. If the pleural space contains trapped air, the lung cannot fully expand. Blood then circulates through nonaerated alveoli, leading to hypoxia. Despite thin, healthy patients can generally tolerate the complete collapse of one lung. Tension pneumothorax starts in a similar manner; however, the pathophysiology soon diverges. Some lung injuries act as a one-way valve. Inspiration pulls air into the pleural space. Expiration compresses the lung and obstructs air egress. As pleural pressure builds, the mediastinum is pushed to the contralateral side (shifting the trachea), eventually kinking the superior vena cava and inferior vena cava. Venous pressure then rises (distending the neck veins) and venous return falls. As preload drops, cardiac output drops, and then blood pressure drops. Patients die from cardiogenic shock, not hypoxia, although hypoxia may also be present. If a patient with a hypotensive injury becomes hypotensive after intubation, consider tension pneumothorax. Positive pressure ventilation can rapidly raise the intrapleural pressure in these patients.

Tension pneumothorax is both rapidly lethal and rapidly correctable. There are several mandatory treatments. The first should be decompression. If you suspect tension pneumothorax, perform needle thoracostomy (or expeditiously place a chest tube). Do not wait for chest radiograph confirmation. Use the largest IV catheter immediately available (ideally 14 or 16 gauge). Place the catheter in the second or third intercostal space, in the midclavicular line, aiming toward the back. This will decompress the pleural space. Whether or not the patient had a tension pneumothorax, the outcome will be a simple pneumothorax. A chest tube should be placed at the earliest opportunity. A small chest tube (e.g., 20 French) placed anteriorly will work, but most chest injuries involve some degree of bleeding and a large chest tube (e.g., 36 French) is preferable. Place it in the fifth intercostal space in the midaxillary line high enough to avoid hitting the liver or spleen. Although tube thoracostomy is optimal treatment, it takes a few minutes to complete. As death can occur rapidly, needle thoracostomy should be considered first unless you have all the equipment actually in your hands.

Volume loading should be done simultaneously for treating a tension pneumothorax. If you have a patient who is hypotensive and hypoxic with distended neck veins and tracheal shift, turn up the IV as you look for a catheter for needle thoracostomy. Increasing the venous volume (and pressure) will overcome the venous obstruction (until the mediastinum shifts further). This will not treat the hypoxia, but it will raise the blood pressure for a few minutes. As with other interventions,
the goal of initial trauma care is to buy time for definitive treat-

Open Pneumothorax and Flail Chest

In an open pneumothorax, there is a large hole into the chest. As the patient tries to breathe, air moves in and out through the hole. For this reason, an open pneumothorax is also known as a sucking chest wound. Intrapleural pressure never falls, so the ipsilateral lung never expands. There are two treatment op-
tions. If you cover the hole, you create a simple pneumothorax,
which can be treated with tube thoracostomy. If you intubate the patient, positive pressure ventilation will expand both lungs regardless of the presence of an open pneumothorax.

Flail chest has similar pathophysiology. If three or more ribs are broken in two places, the “flail” segment moves in and out as the patient tries to breathe. As with open pneumothorax, there are three choices: you can place a chest tube, intubate the patient, or both. Unfortunately, the force needed to cause these injuries usually damages the adjacent lung. Although treating the flail segment is easy, patients may still die from the associated pulmonary contusion and hypoxia.

Cardiac Tamponade

Beck’s triad (hypotension, jugular venous distention, and muffled heart sounds) and pulsus paradoxus (an exaggerated drop in systolic blood pressure of >10 mm Hg with inspiration) are the hallmarks of cardiac tamponade. These clinical signs are less reliable in trauma. Hypotension is nearly universal, hypo-
volemia may prevent jugular venous distention, and ED noise obscures heart sounds. Clinical suspicion (any wound near the heart) is essential to making this diagnosis, although cardiac tamponade has been rarely reported after minor chest trauma.

Cardiac tamponade is both rapidly lethal and rapidly cor-
rectable. For this reason, patients who present in shock after chest trauma have a better chance of survival if they present with cardiac tamponade (13). As blood enters the rigid pericar-
dial sack, it prevents the heart from filling during diastole. Venous return is obstructed, venous pressure rises, and cardiac output falls. The rapid infusion of IV fluid will transiently raise the blood pressure (14), but decompression is key, followed by definitive correction of the underlying injury. The pathophysi-
ology is similar to tension pneumothorax. Although rare, ten-
sion pneumomediastinum presents (15) in an identical fashion.

Peripheral Arterial Injuries

Significant arterial bleeding from extremity laceration is some-
times “audible.” Direct pressure is the treatment of choice, particularly with peripheral arterial injuries. Tourniquets cut off collateral circulation and are best reserved for those situa-
tions where you need to stop bleeding while carrying the vic-
tim to safety. Direct clamping is instantaneous effective, but may be difficult in the emergency room with limited light, suc-
tion, and retraction. Even when applied properly, a clamp may crush the artery, reducing the length available for a primary anastomosis. As arteries travel with nerves and veins, direct clamping may damage adjacent structures. For these reasons, direct pressure is preferred, even though it may fully occupy one person.

Resuscitation

Resuscitation starts in the field and continues after arrival. Ad-

minister fluid rapidly if justified by the mechanism of injury. It is rare for a patient to develop congestive heart failure from resuscitation in the emergency room even if they have underly-
ing cardiac disease. In contrast, underresuscitation is common (18). Young, athletic patients may be able to compensate for significant blood loss without tachycardia or hypotension. Es-

tential hypertension and heart block also make it difficult to interpret vital signs in the elderly. As a sign of shock, tachycardia is more sensitive than hypotension; however, tachycardia may reflect pain rather than blood loss. With the foregoing caveats, continuously monitoring the vital signs is the best way to gauge the efficacy of ongoing resuscitation (Table 72.2).

If you can palpate a pulse, you can estimate the blood pres-
sure. As a general guide, a palpable carotid pulse implies that the blood pressure is at least 60 mm Hg; a femoral pulse implies that the blood pressure is over 70 mm Hg, and a radial pulse implies 80 mm Hg.

Intravenous Access

“Two large-bore IVs, placed at different sites” is a tenet of trauma resuscitation. With too many IVs, the tubing tangles and hampers patient transfer. “Large bore” implies that the line can be used to rapidly transfuse blood. The infusion rate de-
pends on pressure and resistance. Commercial warming equip-
ment (e.g., Level 1 or Rapid Infusion System) as well as sim-
ple pressure bags can greatly increase the transfusion pressure. Resistance varies with blood viscosity (which increases with refrigeration) and line (tubing plus IV catheter) impedance. Large IV catheters (>8 French) are ready available and can be placed easily using the Seldinger technique. Small IV catheters, the transfusion rate is limited by the tubing itself. A shorter length and larger diameter are advantageous. Catheter impendence increases exponentially (to the fourth power of the radius) as the catheter gets smaller. For this reason, 18-gauge catheters can be problematic and smaller catheters should not be used.

If you place femoral lines in patients with pelvic trauma, you may find one of your lines infusing into the peritoneal cavity through a lacerated iliac vein. Whenever possible, place IV lines...
Colloid, Crystalloid, and Blood Substitutes

How best to replace lost blood has been a perennial topic of controversy. Restoring volume can be achieved with colloid or crystalloid. Restoring oxygen-carrying capacity requires red cells.

Crystalloid should be used first in trauma resuscitation. It is readily available, inexpensive, and free of viruses and allergic reactions. As rapid infusion may be necessary, it must be isotonic. Normal saline (0.9% NaCl) is the preferred solution if you need to administer blood through the same line. Since normal saline contains 154 mEq of sodium and no potassium, large amounts lead to hyperchloremia and hypokalemia. Ringer lactate and Ringer acetate avoid this problem by reducing the sodium and adding potassium (and calcium).

Unlike blood, which is confined to the vasculature, crystalloid equilibrates throughout the interstitial and intracellular spaces. As a consequence, 3 liters of crystalloid is needed to replace 1 liter of blood. ATLS recommends starting O-negative or type-specific blood (if available) after 2 liters of crystalloid have been given and the patient remains hypotensive. Nonetheless, many other injuries remain. Some are severely contributing to death and disability. To avoid missing rapidly correctable patient. After ruling out injuries that are away from the site of trauma. Choose a different extremity for the second line. If the first is in the arm, place the second in the groin or leg (and vice versa). Separating IV lines maximizes the likelihood that infused fluid will reach the heart.

**TABLE 72.2**

<table>
<thead>
<tr>
<th>BASED ON PATIENT'S INITIAL PRESENTATION</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
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<tr>
<td>Blood loss (mL)</td>
<td>Up to 750</td>
<td>750–1,500</td>
<td>1,500–2,000</td>
<td>&gt;2,000</td>
</tr>
<tr>
<td>Blood loss (%)</td>
<td>Up to 15%</td>
<td>15%–30%</td>
<td>30%–40%</td>
<td>&gt;40%</td>
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<tr>
<td>Blood pressure</td>
<td>&lt;100</td>
<td>&gt;100</td>
<td>&gt;120</td>
<td>&gt;140</td>
</tr>
</tbody>
</table>

From American College of Surgeons Committee on Trauma. ATLS Advance Trauma Life Support for Doctors. Chicago: American College of Surgeons; 2004:74 (Table 1).
elsewhere in this book. Building on lessons from the primary survey and resuscitation, the next chapter reviews the secondary and tertiary surveys, diagnostic evaluation, and definitive treatment.

References

27. American College of Surgeons Committee on Trauma. ATLS Advanced Trauma Life Support for Doctors. Chicago, IL: The American College of Surgeons; 2004:15.

CHAPTER 73 SECONDARY AND TERTIARY TRIAGE OF THE TRAUMA PATIENT

ROBERT D. WINFIELD • LAWRENCE LOTTMENBERG

The previous chapter covered the initial assessment and care of the injured trauma patient. Following the period of stabilization and the management of immediately life-threatening injuries described therein, the patient will make the transition to the more comprehensive capabilities of the inpatient setting. This chapter is focused on that critical period of time that begins with transfer to the intensive care unit, in which transport, transfer of care to the intensive care unit team, the gathering of additional information, continued resuscitation, and a more complete and thorough assessment of the patient’s injuries are undertaken. Additionally, this chapter will address some of the more common injuries that are associated with delayed presentations, and cover current diagnosis and management strategies in these situations.

IMMEDIATE CONCERNS

Patient Transport to the Intensive Care Unit

Of immediate concern following stabilization is safe transport of the critically injured patient from the emergency department
TABLE 73.1

AMERICAN COLLEGE OF CRITICAL CARE MEDICINE/SOCIETY OF CRITICAL CARE MEDICINE GUIDELINES FOR INTRAHOSPITAL TRANSFER OF THE CRITICALLY ILL PATIENT

Pretransport coordination
Continuity of care ensured by physician-to-physician and/or nurse-to-nurse communication to review patient condition and the treatment plan
Confirmation by the receiving location that it is ready to receive the patient
Coordination of appropriate hospital personnel (e.g., respiratory therapy) to be available on patient arrival

Accompanying personnel
Minimum of two people
In unstable patients, a physician with training in airway management, advanced cardiac life support (ACLS), and critical care training or equivalent

Accompanying equipment
A blood pressure monitor (or standard blood pressure cuff), pulse oximeter, and cardiac monitor/defibrillator accompany every patient without exception
When available, a memory-capable monitor with capacity for storing and reproducing patient bedside data
Airway management equipment and oxygen source to supply for projected needs and 30-minute reserve
Basic resuscitation medications (epinephrine, antiarrhythmic agents)
If a transport ventilator is to be employed, it must have alarms to indicate disconnection and excessively high airway pressures and must have a backup battery power supply

Monitoring during transport
At a minimum, continuous electrocardiographic monitoring, continuous pulse oximetry, and periodic measurement of blood pressure, pulse rate, and respiratory rate


or trauma bay to the intensive care unit setting. While the practice of moving the patient between these two settings would seem to be quite simple, numerous authors have described the pitfalls associated with the transfer of patients within a given facility (1–4). In 2004, the American College of Critical Care Medicine and the Society of Critical Care Medicine released specific guidelines for appropriate intrahospital transfer of critically ill patients (5). These guidelines are summarized in Table 73.1. Briefly, they highlight the need for appropriate pretransport communication between the transporting and receiving teams, the presence of appropriate numbers of adequately trained personnel in the transport, the equipment and medications that should accompany the patient on the transfer, and the minimal level of monitoring that the patient should receive during transport.

Communication between Trauma Team and Intensive Care Unit Providers

Upon the arrival of a critically injured trauma patient, communication should begin between the trauma team and intensive care unit (ICU) providers. Initial impressions of the extent and severity of injuries, known medical and surgical history, and immediate surgical plans can all be helpful to the ICU team in making arrangements for appropriate equipment, medications, and personnel to be available upon patient transfer to the ICU. Physician-to-physician communication will vary depending on whether or not the ICU is an open or closed unit. In an open ICU, the trauma surgeon responsible for admitting the patient will remain primarily responsible for the patient’s care throughout his or her hospitalization, including all moment-to-moment ICU decisions. This clearly precludes the need for a handoff of care responsibilities. In a closed ICU, a designated physician intensivist or intensivist team will assume primary responsibility over the patient’s care. In the latter situation, concise yet complete discussions should ensue between the trauma surgeon and intensivist regarding the patient’s status in order to minimize disruption upon transfer of care.

Additionally, the need to communicate with nursing staff and hospital administration regarding needs for bed space cannot be underestimated. In busy tertiary care centers, particularly level I trauma centers, intensive care unit bed space is at a premium. Unidirectional flow of trauma patients (from the emergency department to radiology to the ICU, without a return to the emergency department) is dependent on keeping the bed control coordinator informed of needs. In single or dual trauma centers, this unidirectional flow is highly desirable, but...
in mass casualty situations, it is essential to the successful triage and management of the injured patients.

**OBTAINING THE PATIENT’S HISTORY AND HISTORY OF INJURY**

**Communication with Patients/ Family Members**

Oftentimes, communication with patients is not possible in critically ill trauma patients, and much of the information that will subsequently be known about the trauma victim is obtained through discussion with family. Interaction with the family of a recently injured patient can pose incredible challenges for the trauma or intensive care unit provider. In a brief period of time, the physician must explain the circumstances that led to the patient’s injuries, what has been done for the patient up to this point, injuries that have been identified, the prognosis (if this can be estimated), and immediate plans for the patient’s care. Additionally, this will be a time to obtain family contact information and valuable background information about the patient and his or her relevant health history, as well as discuss informed consent for any pending invasive procedures. While this can be a daunting task, a sensitive and systematic approach will ensure effective and thorough communication that engenders trust among the loved ones of the patient and allows the care providers to obtain needed information.

The time following notification of a severe injury to a loved one is a time of intense emotion. Many authors have reported that signs and symptoms of anxiety, depression, and even post-traumatic stress disorder (PTSD) are present in family members of trauma victims and intensive care unit patients (6-8). It has been suggested that some of these symptoms may be lessened by early communication with the family as this allows the family members to transition to an emotional state where they are capable of dealing with the issues at hand (9,10). Cross et al. performed a study in which they observed the time that elapsed between the arrival of family members and the time when a physician member of the trauma team held a discussion with the family (9). They found that families waited an average of 37 minutes in the hospital before being approached by a trauma physician. They concluded that this was an unacceptable wait time, as it was added to an average 38-minute transport time to the hospital. The study indicated that this wait time was often prolonged because of failure to notify the physician that the family had arrived, and physician delays in approaching the family secondary to patient care issues, awaiting radiologic studies, and simply forgetting that the family was waiting. They recommended the designation of a member of the caregiving team to be the liaison to the family as soon as possible to prevent undue emotional duress.

On approaching the family, Epperson recommends three steps in alleviating anxiety: the provision of brief and accurate information about patient status, an explanation of procedures currently being performed, and allowing time for the family members to communicate their initial impressions regarding the trauma and its impact (9,10). This should promote open discussion and a sense of trust for the health care providers in the trauma team. Interestingly, the satisfaction and comprehension of the family under these circumstances appears not to be dependent on communication with an attending or fellow, indicating that a resident may be designated to perform this important task (11).

Following adequate time for the family to voice concerns, as thorough a history as may be obtained should be undertaken in order to plan for special care needs of the individual patient. Particular attention should be paid to chronic diseases with known end-organ dysfunction, anticoagulation agents (aspirin, warfarin, clopidogrel, etc.), and patient allergies. Finally, with the arrival of appropriate family members, informed consent should be obtained for any planned invasive procedures. This allows for the possibility of early involvement of the family in the patient’s care plans, and maximizes the chances that the patient will receive care that is in keeping with his or her personal beliefs. One method that we have found helpful in our institution’s intensive care unit is the use of a standardized ICU “universal” consent form, which covers many of the commonly performed procedures in the ICU (Fig. 73.1). This allows us to obtain consent for many procedures simultaneously, allowing us to rapidly perform life-saving procedures with the knowledge that the family has agreed to their performance. Additionally, it promotes consideration of, and discussion about, the opinion of the family regarding the patient’s desires for life-sustaining measures.

**The Role of the Social Worker**

The social worker has unique training that focuses on the concept of the patient as a member of a family system, and this makes him or her an invaluable part of an optimally functioning trauma team. Oftentimes, the social worker is the first member of the team to meet with the family following a traumatic injury and he or she continues to play an integral role in the patient’s care plan throughout the patient’s hospital course. The social worker has the ability to obtain insight into family dynamics and resources, and is likely the first individual that truly begins discharge planning on admission of a patient to the hospital. Additionally, the social worker will have the opportunity many times to interact with law enforcement officials and get a thorough description of the circumstances surrounding the issue, even as the acute resuscitation and management phase is taking place.

**Interaction with Law Enforcement**

Traumatic injury often involves interaction with officers of the law. In circumstances of motor vehicle collisions and assaults in particular, law enforcement officials may be present in the trauma bay and the intensive care unit to provide and gather additional information as well as obtain blood samples for alcohol and drug testing. Cooperation is obviously encouraged; however, the patient’s care must remain the priority under these circumstances. Additionally, there will be situations in which patients are found after proven or suspected assault. Under these conditions, reporting of a suspected assault and relevant details should be communicated with law enforcement officials in keeping with state and local reporting standards.
I, the undersigned, understand that the adult intensive and intermediate care units ("critical care units") are places where seriously ill patients are cared for by specially trained staff. The critical care staff works closely together as a team to provide the best possible care. The critical care team uses a number of specialized machines and devices, called monitors, to frequently check the heartbeat, blood pressure, and breathing. Machines that help the patient breathe, called mechanical ventilators, may also be used.

I have been informed that patients in the adult critical care units often undergo certain medical procedures and/or treatments, either to help determine what is wrong, or to relieve symptoms or resolve problems.

I understand that some of these procedures may be performed more than once during a patient's admission. These commonly performed procedures, their use in diagnosis and treatment, as well as the substantial risks and possible complications involved, have been explained to me by Dr._____.

I have also read, or had read to me, the information sheet entitled "Commonly Performed Procedures and Related Complications," a copy of which is attached to this form and which briefly describes each of these commonly performed procedures, and their substantial risks, potential benefits and medically reasonable alternative treatments. I have had an opportunity to ask questions of Dr._____.

I understand that the information I have received about risks is not exhaustive, and there may be other, more remote risks. I have received no guarantees from anyone regarding the results that may be obtained from any of these treatments or procedures.

I understand the potential benefits and drawbacks, potential problems related to recuperation, the likelihood of success, the possible results of non-treatment, and any medically reasonable alternatives associated with these commonly performed procedures. I also understand that a refusal to consent to any of these procedures may have a serious adverse impact on my health and/or ability to recuperate.

I understand that some of these procedures may be performed more than once during a patient's admission. These commonly performed procedures, their use in diagnosis and treatment, as well as the substantial risks and possible complications involved, have been explained to me by Dr._____.

I have been informed that patients in the adult critical care units often undergo certain medical procedures and/or treatments, either to help determine what is wrong, or to relieve symptoms or resolve problems.

I understand that the information I have received about risks is not exhaustive, and there may be other, more remote risks. I have received no guarantees from anyone regarding the results that may be obtained from any of these treatments or procedures.

I understand the potential benefits and drawbacks, potential problems related to recuperation, the likelihood of success, the possible results of non-treatment, and any medically reasonable alternatives associated with these commonly performed procedures. I also understand that a refusal to consent to any of these procedures may have a serious adverse impact on my health and/or ability to recuperate.

I,______________________, consent to the treatments and/or procedures indicated by my initials below, which in the judgment of my critical care units physicians may be considered necessary or advisable for ____________________'s diagnosis or treatment, and which may be performed by any of the adult critical care units' physicians and their associates and assistants (including resident physicians). I understand that this consent will be considered good for my/the patient's critical care unit admission, up to 60 days, and that I may at any time withdraw my consent to any treatment or procedure.

I understand that the information I have received about risks is not exhaustive, and there may be other, more remote risks. I have received no guarantees from anyone regarding the results that may be obtained from any of these treatments or procedures.

I understand the potential benefits and drawbacks, potential problems related to recuperation, the likelihood of success, the possible results of non-treatment, and any medically reasonable alternatives associated with these commonly performed procedures. I also understand that a refusal to consent to any of these procedures may have a serious adverse impact on my health and/or ability to recuperate.

Procedures
Arterial Line Insertion......................................_____ Sedation Maintenance or Procedural.................._____
Pulmonary Artery Catheter Placement...................._____
Central Venous Line Insertion.............................._____
Peripherally Inserted Central Catheter................._____

Consent for Commonly Performed Procedures in the Adult Critical Care Units

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Initials of patient or representative</th>
<th>Procedures</th>
<th>Initials of patient or representative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial Line Insertion</td>
<td>.............................</td>
<td>Sedation Maintenance or Procedural</td>
<td>.............................</td>
</tr>
<tr>
<td>Pulmonary Artery Catheter Placement</td>
<td>.............................</td>
<td>Intubation &amp; Mechanical Ventilation</td>
<td>.............................</td>
</tr>
<tr>
<td>Central Venous Line Insertion</td>
<td>.............................</td>
<td>Bronchoscopy</td>
<td>.............................</td>
</tr>
<tr>
<td>Peripherally Inserted Central Catheter</td>
<td>.............................</td>
<td>Chest Tube Insertion</td>
<td>.............................</td>
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</table>

FIGURE 73.1. The “universal” intensive care unit consent of Shands Hospital at the University of Florida.

**REASSESSING THE ABCs WHILE MAINTAINING VITAL FUNCTION**

**Assessment Methods**

As previously mentioned, the transport of the patient from the trauma bay to the ICU can be a time of potential peril. As such, arrival in the ICU represents a time for reassessment of patient status, particularly the ABCs. None of the methods subsequently listed should, in any way, disrupt the continued resuscitation or care of the patient.

The airway may be assessed in standard fashion in the awake, nonintubated patient by confirming that the patient is able to speak. In circumstances where the patient was intubated during resuscitation, confirmation of endotracheal or nasotracheal tube placement should be undertaken using confirmation of end-tidal carbon dioxide and capnography. The
patient's care record should indicate the depth of tube placement. Should this be in question, or if a variation is present, an anteroposterior (AP) chest radiograph can quickly confirm tube position.

Assessment of breathing should consist of both auscultation of the lungs bilaterally and confirmation of adequate saturation via pulse oximetry. If the patient is being mechanically ventilated, confirmation of appropriate ventilator settings should be established, and if an arterial blood gas has not been performed recently, this may be used to guide changes in ventilator settings.

Finally, evaluation of circulatory status should include auscultation of the heart, confirmation of pulses, measurement of blood pressure, and verification of adequate intravenous access. If blood pressure measurements are felt to be inaccurate, and an arterial line was not placed previously during initial resuscitation, this may serve as a useful adjunct in circulatory management. It may also provide a stable line for the obtaining of arterial blood gas measurements in the ventilated patient. The authors prefer the use of percutaneous lower extremity access for arterial lines in an attempt to avoid the monitoring devices commonly placed on the upper extremities, and due to the frequent occurrence of upper extremity injuries. If the patient has a previously placed arterial line, the line should be zeroed, and appropriate pressure tracing confirmed. With regard to venous access, two large-bore intravenous lines should be adequate, although a large-bore central venous line (e.g., a 9 French introducer) may be preferred in the critically injured patient as it is less likely to become dislodged and has the potential to offer the benefits of central venous pressure measurements as well as superior vena cava mixed venous oxygen saturation measurements; both of these may have the added benefits of assisting in guidance of fluid resuscitation. Furthermore, large-bore central access may be used for rapid infusion of crystalloid and blood products, and can provide a port of entry for a right heart catheter should this be desired. The authors recommend a subclavian approach due to the greater incidence of catheter-related bloodstream infections in alternate sites, as well as the difficulty in accessing the internal jugular vein in the patient with suspected cervical spine injury (12). The femoral vein may also be utilized for rapid access; however, femoral venous catheters should be removed within 24 hours due to the risk of deep vein thrombosis (12).

**Pitfalls**

The intubated patient can have his or her airway disrupted by any number of usual and customary motions during transport, and in certain cases, loss of airway represents a potentially catastrophic complication. As such, it is generally good practice to have an appropriately trained individual responsible for maintenance of airway at all times. This person should monitor the position and security of the tube, as well as the connection of the tube to the Ambu-bag or ventilator. Ideally, this person should be comfortable with intubation and surgical airway management. Pharmacologic agents can be of great assistance in preventing loss of airway, as analgesics, anxiolytics, and paralytics can alleviate patient agitation. In our experience, intermittent administration of paralytic agents has decreased the incidence of tube dislodgement during transport.

Dislodgement of the tube should be dealt with emergently. The simplest solution is to perform bag-mask ventilation until such time as a controlled reintubation may take place. Should this fail, a laryngeal mask airway or Combitube may provide a temporary alternative. Finally, should these methods be unsuccessful, a cricothyrotomy or tracheostomy should be undertaken immediately.

While dislodgement of the endotracheal tube represents the issue that requires attention most urgently, it is important to remember that advancement of the tube may pose a problem as well. In this circumstance, the patient may be experiencing a right mainstem intubation, and is undergoing single lung ventilation only. This can be detected quickly by physical examination, noting absent left-sided breath sounds and absence of left-sided chest movement on inspiration. Additionally, a chest radiograph may aid in identification of this problem.

When assessing the adequacy of ventilation in the patient, it was mentioned previously that pulse oximetry may be used to evaluate oxygen saturation. This has limitations, though, as adequate oxygen saturation may not reflect adequate oxygen tension (13), and in hypotensive patients, tremendous error may be seen in pulse oximetry measurements (14). As such, should there be any question regarding the sufficiency of ventilation, an appropriately obtained arterial blood gas should provide the needed information.

**PERSISTENT SHOCK**

**Persistent Shock in the Multisystem Trauma Patient**

The patient arriving in the ICU in persistent shock poses a challenge for caregivers, who are attempting to quickly gain hemodynamic and ventilatory stability. In the trauma patient, it is essential to remember that often the hemorrhage is not the sole source of bleeding, and persistent shock is hemorrhage until proven otherwise, and a meticulous search for hidden sources of bleeding is indicated. There are a number of sources that may not have been considered during initial evaluation and resuscitation (but always should be). Open wounds can ooze a large amount of blood, and should be managed with pressure dressings. Should the wound involve an open fracture, it should be placed in anatomic continuity and fixed with a temporary splint. Scalp lacerations can bleed profusely, but a quickly performed locked running suture with a large monofilament nylon suture may be placed in anatomic continuity and fixed with a temporary splint. A mangled extremity presents a potentially difficult challenge, but a simple one-stage tourniquet can provide a temporary measure until definitive management can be pursued. Finally, hemorrhage may also result from other hidden sources; these will be covered in the subsequent section of this chapter on missed injuries.

**Management of the Patient in Persistent Hemorrhagic Shock**

Patients may experience persistent hemorrhagic shock not only through a discrete bleeding injury, but also as a result of the vascular permeability that results from the inflammatory response to injury and the coagulopathy that occurs when large volumes
The pursuit of massive transfusions in the context of trauma care is a testament to the critical nature of surgical emergencies. The protocols outlined here are developed to ensure the most efficient and effective use of blood products, particularly in the face of significant blood loss and ongoing hemorrhage. The schedule for massive transfusion protocol at Shands at the University of Florida, as seen in the table, is designed to address these needs.

<table>
<thead>
<tr>
<th>Shipment</th>
<th>Red Blood Cells</th>
<th>Plasma</th>
<th>Platelet Dose</th>
<th><strong>Cryo</strong></th>
<th>***rFVIIa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 (O-Neg)</td>
<td>4(AB)</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
</tr>
</tbody>
</table>

The shipment number refers to the allotment of blood components (Red Blood Cells, Plasma, Platelets, Cryoprecipitate, and rFVIIa) provided at each step of massive transfusion. At the conclusion of each step, the decision must be made by the team providing care whether or not to order the next shipment of blood products.

**Definition of massive transfusion**

Massive transfusion at Shands at the University of Florida is defined as a presumed need for the transfusion of at least 10 units of packed red blood cells (PRBC) in an adult patient or at least five (5) units of PRBC in a child within a short time frame (i.e., two (2)-hour time period).

*Shipment 1 is located in the Satellite Blood Bank Refrigerator, located in the Emergency Department and Operating Room.

**Cryo=Cryoprecipitate

***Recombinant Factor VIIa (rFVIIa) is not routinely shipped and must be ordered from Pharmacy. These are recommended intervals if rFVIIa is clinically warranted.

FIGURE 73.2. The massive transfusion protocol of the Acute Care Surgery Service of Shands Hospital at the University of Florida, Appendix A.

of resuscitation are administered. Recently, it has been advocated that resuscitation of the critically injured trauma patient in shock is best performed with blood and fresh frozen plasma in a 1:1 ratio (15). In patients who have experienced significant blood loss, are in patient shock, and require greater than 10 units of blood replacement, it is helpful for a trauma center to have a massive transfusion protocol in place to guide management. This will ensure the most efficient and effective use of blood products. An example of the massive transfusion protocol used at the authors' institution is seen in Figure 73.2.

As mentioned, an additional concern in the patient with severe injury and large resuscitations, particularly in the setting of a massive transfusion, is coagulopathy. Some authors have advocated the use of recombinant factor VIIa (rFVIIa) as an adjunct measure in the control of ongoing hemorrhage in this setting. Martinowitz et al. performed an early look at the use of rFVIIa in seven trauma patients, noting a significant decrease in transfusion requirements, concluding that rFVIIa could be a useful adjunct treatment in trauma patients (16). Dutton et al. at Maryland reviewed their experience using rFVIIa in 81 trauma patients with coagulopathy and hemorrhage, noting that there was a reversal in coagulopathy, but not an improvement in mortality; however, they pointed to the fact that rFVIIa was often used as a "therapy of last resort" and indicated that more information was needed regarding the timing of administration (17). Perkins et al. recently looked at combat-injured patients who received “early” (before 8 units of blood) or “late” (after 8 units of blood) rFVIIa during massive transfusion, again demonstrating a decrease in red blood cell use (a 20% decrease in their series) without a decrease in mortality (18). Finally, there has been a set of parallel, randomized, double-blinded clinical trials reported on the subject (19). Once again, a decrease in transfusion requirements was noted, but without a significantly improved mortality. So, while there have been some promising results in that patients who have received rFVIIa require less transfusions, there has yet to be a study demonstrating a survival benefit or improved outcome with its use. There is currently an ongoing trial evaluating this issue.

**Goal-directed Therapy**

Goal-directed therapy refers to the use of resuscitation end points to guide management of the patient in shock, and has been the source of controversy in the medical and surgical literature for greater than a decade. While there is a general consensus that maintenance of tissue oxygenation is beneficial in preventing the sequelae of shock, debate has centered on the specific end points that should be utilized, whether a pulmonary artery catheter should be used, and whether normal or supranormal values should be pursued in these patients. This section...
reviews the concept of goal-directed therapy in the traumatically injured patient, along with an overview of some of the broad concepts within goal-directed therapy.

**Goal-directed Therapy in the Trauma Patient**

Gattinoni et al., as part of the SvO₂ Collaborative Group, were among the first to assess outcome in patients utilizing goal-directed therapy, performing a multicenter study of critically ill patients, including those with multiple injuries secondary to trauma (20). In their study, they randomized hospitalized critically ill patients into groups designed to achieve one of three ends: a normal cardiac index, a supranormal cardiac index, or a normal SvO₂. In 762 patients divided between the three groups, the authors found no differences in organ dysfunction, intensive care unit length of stay, or mortality. They concluded that there is no benefit in achieving supranormal hemodynamic parameters in critically ill patients. The problems with this study were (a) late entry into the study protocol (by 48 hours), (b) infrequent hemodynamic measurements (every 12 hours), and (c) only 45% of subjects reaching the cardiac index goal and 67% of patients reaching the SvO₂ goal.

In a similar study with a slightly different design, Bauër's group in St. Louis performed a prospective, randomized trial evaluating a group of critically ill patients that included those who were involved in acute trauma (21). Their desired endpoints in the experimental group included goals of resuscitation including oxygen consumption index (VO₂I) of greater than 150 mL/min/m² or oxygen delivery index (DO₂I) of greater than 400 mL/min/m². The control group underwent standard resuscitation using urine output, heart rate, pulmonary capillary wedge pressure, mean arterial pressure, and cardiac index as end points. They showed no difference in mortality or organ failure in patients engaged in goal-directed therapy. They did a subgroup analysis of their trauma patients and demonstrated identical findings. Interestingly, in their experience, they noted a longer length of stay in the experimental group despite similar measures of critical illness, and this approached significance. As with Gattinoni's paper, this study was undertaken in patients already admitted to the intensive care unit.

Around the same time, Bishop et al. further evaluated this issue, focusing solely on severely injured trauma patients in a single-center, prospective, randomized trial at the King/Drew Medical Center in Los Angeles (22). They enrolled study patients into a standardized care pathway in which patients were resuscitated to achieve a supranormal cardiac index, DO₂I, and VO₂I. Control subjects were resuscitated using standard physiologic end points for normal blood pressure, hemoglobin, urine output, and central venous pressure. They showed a decreased incidence of organ failure, as well as a decreased mortality in protocol patients when compared to control, and thus concluded that attaining supranormal hemodynamic characteristics provided a benefit in both morbidity and mortality in severely injured trauma patients. Of significance in this study is that patient resuscitation began on admission, as opposed to the studies by Gattinoni and Durham, where goal-directed therapy began following identification of patients in organ failure already in the intensive care unit.

In a multicenter study that included 139 trauma patients, Shoemaker et al. took a different approach, performing a prospective study of noninvasive methods for monitoring hemodynamic parameters, including bioelectric impedance, pulse oximetry, and transcutaneous oxygen (tcO₂) and carbon dioxide (tcCO₂) measurements (23). They found that in the trauma population, over half had reduced cardiac index (CI) measurements and reduced transcutaneous oxygen measurements, half had decreased oxygen consumption, and nearly half had high transcutaneous carbon dioxide values. Not surprisingly, most had more than one abnormality. Comparing the noninvasive methods to standard pulmonary artery catheter measurements, they found similar disturbances, and showed that regardless of the method used to monitor hemodynamic status, patterns were seen relative to the nadir of the CI that were associated with survival versus nonsurvival, with higher blood pressures and heart rates, as well as lower oxygen saturation preceding and following the nadir in nonsurvivors. Conversely, survivors demonstrated higher initial CI and tcO₂ values, which they speculated might represent lower blood volume deficits or better compensation. They concluded that either noninvasive or invasive methods could be utilized to measure resuscitation status, and could potentially provide data on early identification of low flow and poor tissue perfusion states that precede the nadir of CI that is seen in nonsurvivors. Additionally, they suggested that use of this noninvasive equipment could be helpful in guiding early goal-directed resuscitation for the critically ill patient, beginning in the emergency department or upon admission.

A group that consisted of many of the same investigators as the studies by Bishop and Shoemaker attempted to clarify the issue of supranormal versus normal values in resuscitation of trauma patients (24). In this effort, the authors randomized 75 consecutive patients on admission to either “optimal” resuscitation (CI >4.5, tcO₂ to fraction of inspired oxygen ratio >200, DO₂I >600, and VO₂I >170) or a standard resuscitation with normalization of blood pressure, urine output, base deficit, hemoglobin, and cardiac index. They utilized biomarkers to begin estimating these values prior to ICU admission. They reached “optimal” levels in 70% of the optimal group and 40% of the standard group. While they found no difference in mortality, organ failure, sepsis, or ICU length of stay between the two groups, they performed an additional comparison in which they analyzed patients based on whether or not they reached “optimal” levels and found that both outcome and mortality rates were significantly improved in patients achieving “optimal” resuscitation. Interestingly, they noted that the only factor associated with achieving “optimal” levels was age younger than 40. They suggested that differences in being able to achieve optimal resuscitation indicated a superior physiologic reserve, rather than an effect of the resuscitation efforts themselves, and thus concluded that early goal-directed therapy in trauma patients does not improve outcome.

Finally, Balogh et al. in Houston noted that achieving supranormal resuscitation end points requires additional fluid, and indicated that this led to a greater incidence of intra-abdominal hypertension and abdominal compartment syndrome (25). They performed a retrospective analysis of patients in their trauma intensive care unit, looking at patients who underwent supranormal resuscitation versus those undergoing standard resuscitation. They found that patients in the supranormal group received more fluid, had higher gastric partial carbon dioxide pressure, and had higher lactate levels, with no difference in survival.
dioxide minus end-tidal carbon dioxide (GAPCO2) measurements, and had greater incidences of intra-abdominal hypertension and abdominal compartment syndrome. Additionally, they found a significantly increased incidence of organ failure and death in the supranormal resuscitation group. They concluded that supranormal resuscitation was deleterious when compared with standard resuscitation.

### Right Heart Catheterization Levels

Values obtained through right heart catheterization are considered the “gold standard” physiologic measurements in that which noninvasive cardiovascular measurements are compared. The primary end point obtained through right heart catheterization is that referred to in the literature is DO2I, which is a function of cardiac index, hemoglobin, and oxygen saturation. The previously mentioned articles provide a sampling of the mixed data regarding the use of DO2I as an indicator of resuscitation in the critically ill (20,23–25). Utilizing a new-generation pulmonary artery catheter, the right ventricular ejection fraction (or right ventricular end-diastolic volume index [RVEDVI]) may be used as a surrogate marker for assessment of preload. Maintenance of RVEDVI greater than 120 mL/m2 has been associated with improved outcome in trauma patients (30,36,37).

### Alternative Methods

Thoracic electrical bioimpedance (TEB) was used in the previously mentioned study by Shoemaker et al., and in an additional study of noninvasive monitoring of blunt trauma patients by Velmahos at the same institution (23,38). In each of these, good correlation between TEB and simultaneously obtained right heart catheter cardiac output measurements existed, and its use was recommended as a noninvasive alternative to right heart catheterization. Lithium dilution cardiac output (LiDCO) utilizes a venous lithium chloride injection, which is then measured at an arterial catheter site and used to calculate cardiac output. It has been shown to correlate well with standard right heart catheter values, even when the lithium is injected peripherally (30,39), although it has not been studied in the traumatically injured. It does carry the benefit of not requiring calibration with an existing right heart catheter (30).

Esophageal Doppler monitoring (EDM) is a less invasive method (the Doppler probe is placed within the esophagus) for measuring both preload and continuous cardiac output that has shown benefit in the reduction of postoperative recovery time following surgery and in septic patients, although its use has not been evaluated in trauma patients (30,40–42). Near-infrared spectroscopy (NIRS) uses near-infrared light absorption by hemoglobin, myoglobin, and cytochrome aa3 oxidase to calculate tissue oxygen saturation (StO2) (30). NIRS has been shown to correlate with systemic oxygen delivery (43), in severely injured trauma patients showed a parallel with DO2I values (44), and using cytochrome aa3 measurements in 24 severely injured trauma patients, illustrated that early evidence of mitochondrial dysfunction suggested a predisposition for progression to multisystem organ failure (45).

### BLUNT CARDIAC INJURY

**Definition/Discussion**

In 1992, Mattox et al. proposed that the broad term myocardial contusion and myocardial concussion be replaced with the phrase blunt cardiac injury (46). They further suggested that...
Blunt cardiac injury (BCI) be classified according to descriptors of the specific abnormalities associated with the injury, thus the terms that follow:

Blunt cardiac injury with minor electrocardiogram (ECG) or enzyme abnormality
Blunt cardiac injury with complex arrhythmia
Blunt cardiac injury with coronary artery thrombosis
Blunt cardiac injury with free wall rupture
Blunt cardiac injury with septal rupture
Blunt cardiac injury with cardiac failure

This new terminology allowed for improved description of the injuries, more consistent monitoring and management of each specific type of injury, and descriptions of the short- and long-term effects of having sustained such an injury. It is estimated that 20% of patients who die in the prehospital setting have sustained cardiac injuries, and an additional 30,000 patients per year with BCI survive to hospital discharge (47).

Clinical Suspicion

BCI must be suspected in any case involving blunt thoracic trauma. In most cases, this will involve a motor vehicle collision, but any of a number of mechanisms may lead to these injuries, including bicycle crashes, falls, blast injuries, sports-related trauma, and assaults (48). Because of the nature of these injuries, other concomitant injuries will be seen, with head injury, rib fracture, extremity injuries, hemothorax, sternal fracture, pulmonary contusion, aortic or great vessel injury, pneumothorax, solid abdominal organ injuries, and flail chest most commonly noted (47,48). In the conscious patient, complaints of chest pain may heighten suspicion, but due to the severe multisystem nature of these injuries and concurrent head injuries, pulmonary contusion, aortic or great vessel injury, rib fracture, extremity injuries, hemothorax, sternal fracture, pulmonary contusion, aortic or great vessel injury, pneumothorax, solid abdominal organ injuries, and flail chest most commonly noted (47,48).

Monitoring of the patient with diagnosed BCI is largely dependent on the type of injury sustained. Blunt chest injury sequelae may range from benign ECG abnormalities to mortal hemorrhage. Management must be tailored to the pattern of injury.

There are currently no specific diagnostic criteria for BCI (46–48). In cases of suspected or possible BCI, it is essential to perform a systematic evaluation. Again, mechanism of injury is important to obtain from the patient, those present at the scene, or first responders. A complete thoracic and cardiovascular exam will yield hints of the diagnosis, with hypotension, visual sequelae of chest trauma (abrasions, bruising, seatbelt sign, or steering wheel imprint), flank chest, rib fractures, sternal fractures, abnormal heart sounds (muffling, distance, S1, S2, murmurs, bruits, or rubs), and jugular venous distention all suggestive (47). Following the history and physical exam, and during the trauma evaluation, the Focused Assessment with Sonography in Trauma (FAST) exam should be performed to look for fluid in the pericardium. It has been suggested by more than one series that the pericardium can be evaluated with tremendous accuracy during a trauma evaluation using this technology (49,50).

Diagnosis/Monitoring

Simultaneously, or in the ICU, ECG and chest radiograph may be obtained, both of which may provide findings that are nonspecific for, but suggestive of, this injury. The utility of ECG in BCI has been evaluated by a number of authors, all of whom found that abnormal ECG findings on admission or early in the hospital course were associated with complications, or that absence of findings was associated with a lack of complications and warranted no further studies (51–56). There are no ECG findings that are pathognomonic for BCI; however, the finding of any abnormality on ECG should prompt further workup. With regard to the chest radiograph, there are no findings that will definitively demonstrate cardiac injury, but they often prove useful by demonstrating some of the associated injuries that may accompany a BCI.

Like monitoring, management is dependent on the type of injury sustained. Blunt chest injury sequelae may range from benign ECG abnormalities to mortal hemorrhage. Management must be tailored to the pattern of injury.

The majority of patients will be categorized as having BCI with minor ECG or enzyme abnormality. While these findings may be initially benign, both Marenza et al. and Velmahos et al. found in their respective series that ECG and/or enzyme abnormalities with normal blood pressure, continuous monitoring is recommended, but a stay in the intensive care unit is not required (47). The patient with BCI accompanied by hypotension should be continuously monitored in the intensive care unit, with use of right heart catheterization an option in critically ill patients.

Complex arrhythmia with BCI is the next most common injury pattern, and may consist of atrial dysrythmia, ventricular dysrhythmia, or commotio cordis (myocardial concussion). These are seen to occur in anywhere from 2% to 30% of patients (47,48,53) and are managed in accordance with the rhythm disturbance seen. Commotio cordis is a seldom seen injury in which it is postulated that a blow to the chest
results in an immediate rhythm disruption, and is unusual due to its lack of association with myocardial structural damage (66). Despite its rarity, commotio cordis is the second most common cause of sudden death in young athletes due to its association with the generation of ventricular fibrillation (67).

Cardiac failure with BCI is less commonly seen, but should be on the list of differential diagnoses in any patient with persistent hypertension in the absence of a defined injury. Although the diagnosis is suggested by hypotension, tachycardia, jugular venous distention, and an abnormal ECG, definitive diagnosis is often made using echocardiography or right heart catheterization. Supportive care is the mainstay of management in these patients, although there have been reports of successful use of intra-aortic balloon counterpulsation pump (IABP) (68,69).

The use of this modality would require weighing the benefits and risks of hemopump, a requirement of IABP use.

Myocardial wall rupture is even more seldom seen than cardiac failure, primarily because the majority of these patients expire at the scene or en route to the trauma center. It is possible to see a patient with one of these injuries when there is rupture of an atrium, a delayed rupture of a ventricle, or a small, contained pericardial tear (70,71). Should this injury be suspected, or the diagnosis confirmed with echocardiography, immediate operation via open thoracotomy is the sole management option.

Coronary artery thrombosis with BCI is also infrequently seen. The diagnosis is made via findings of ST-segment changes on the anterolateral calf or incisions on the medial and lateral lower extremity is accomplished through either a single incision or multiple incisions. Inadequate, the patient should undergo immediate fasciotomy where therapeutic measures have led to the compartment syndrome, loosening bandages, repositioning the patient, or re-evaluating the diagnosis.

Once diagnosed, management of extremity compartment syndrome is straightforward, depending on the etiology. In cases where therapeutic measures have led to the compartment syndrome, loosening bandages, repositioning the patient, or reducing the degree of traction may provide relief. If these are inadequate, the patient should undergo immediate fasciotomy of the affected compartment. Performance of fasciotomy in the lower extremity is accomplished through either a single incision on the anterolateral calf or incisions on the medial and lateral
multiple organ failure and death. (76). Patients in extremis usually do not tolerate reconstitu-
celiotomy, secondary resuscitation, and delayed reconstruction
continuum that includes primary resuscitation, damage control
inspiratory pressures. This procedure may be performed either
presence of abdominal distention, hypercarbia, and high peak
pressure measurement is accomplished via transduction of the
pressure within the abdominal cavity. Indirect intra-abdominal
obtained with direct needle puncture and transduction of the
patient in the supine position, without abdominal contractions.
A normal peak inspiratory pressure in the range of 85 cm H
progressive failure of ventilation. A typical case of ACS has a
early sign of ACS, but the most reliable clinical indicator is
result in the correction of organ dysfunction. Oliguria is an
is mandatory, and a better outcome is associated with early
secondary to a low cardiac output (CO) associated with ACS
increased intra-abdominal pressure. Richardson and Trinkle de-
cision, and should be considered any time that tension precludes
by injecting 50 to 100 mL of sterile saline into the aspiration
port of the Foley drainage tube. The catheter is then clamped
detail to the aspiration port, and a 16-gauge needle is used
pressure of 25 mm Hg or higher is associated with
organ dysfunction and considered clinical intra-abdominal hy-
pertension. At or above this pressure, surgical decompression
is justifiable.

Intra-abdominal hypertension is graded as described in Table 73.2. Intra-abdominal hypertension is defined as either one or both of the following: (a) an intra-abdominal pressure of 12 mm Hg or greater, recorded by a minimum of three standardized measure-
ments conducted 4 to 6 hours apart; (b) an abdominal perfusion pressure (abdominal perfusion pressure \(= \) mean arterial pressure – intra-abdominal pressure) of 60 mm Hg or less, recorded by a min-
um of two standardized measurements conducted 4 to 6 hours

Clinical Suspicion/Diagnosis/Monitoring

Intra-abdominal pressure is that pressure concealed within the abdomin
abdominal cavity which varies with respiration. A normal intra-abdominal pressure is approximately 5 mm Hg, but may be higher with obesity. Intra-abdominal pressure should be ex-
pressed in mm Hg and measured at end-expiration with the pa-
tient in the supine position, without abdominal contractions. The pressure transducer should be zero-referenced to the level of the midaxillary line. Direct intra-abdominal measurement is obtained with direct needle puncture and transduction of the pressure within the abdominal cavity. Indirect intra-abdominal pressure measurement is accomplished via transduction of the pressure within the bladder. Bladder pressure may be measured

Chapter 73: Secondary and Tertiary Triage of the Trauma Patient

**Clinical Suspicion/Diagnosis/Monitoring**

Intra-abdominal pressure is that pressure concealed within the abdominal cavity which varies with respiration. A normal intra-abdominal pressure is approximately 5 mm Hg, but may be higher with obesity. Intra-abdominal pressure should be expressed in mm Hg and measured at end-expiration with the patient in the supine position, without abdominal contractions. The pressure transducer should be zero-referenced to the level of the midaxillary line. Direct intra-abdominal measurement is obtained with direct needle puncture and transduction of the pressure within the abdominal cavity. Indirect intra-abdominal pressure measurement is accomplished via transduction of the pressure within the bladder. Bladder pressure may be measured...
single or multiple organ system failure that was not previously present (78,79).

Management

Aggressive, nonsurgical, critical care support is of utmost importance to prevent the complications of ACS, and should include continuous cardiorespiratory monitoring and aggressive intravascular fluid replacement, especially when associated with blood loss (81). Excessive fluid resuscitation, however, is detrimental. Oda et al. studied 36 thermally injured patients, with 40% or greater total body surface area burned and without inhalation injuries, who were treated with a fluid resuscitation protocol using hypertonic lactated saline or lactated Ringer solution (82). Their results showed that the total fluid volume infusion requirement and intra-abdominal pressure were significantly lower than those in the lactated Ringer group. The hypertonic lactated saline group developed intra-abdominal hypertension in 14% of patients compared with 50% in the lactated Ringer group, suggesting that hypertonic lactated saline resuscitation may reduce the risk of secondary ACS due to lower fluid volume requirements during the acute resuscitation phase. Nonsurgical management of ACS is listed in Table 73.3.

A pilot study performed by Latenser et al. compared percutaneous decompression versus decompressive laparotomy with a diagnostic peritoneal lavage catheter for acute ACS.
TABLE 73.2
GRADING OF INTRA-ABDOMINAL HYPERTENSION

<table>
<thead>
<tr>
<th>Grade</th>
<th>Intra-abdominal pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12–15</td>
</tr>
<tr>
<td>II</td>
<td>16–20</td>
</tr>
<tr>
<td>III</td>
<td>21–25</td>
</tr>
<tr>
<td>IV</td>
<td>&gt;25</td>
</tr>
</tbody>
</table>


in thermally injured patients (83). Of nine patients who developed intra-abdominal hypertension, five were successfully treated with catheter decompression using a diagnostic peritoneal lavage catheter. The other four—with more than 80% total body surface burn area and severe inhalation injuries—did not respond to percutaneous decompression and required laparotomy. These findings suggest an important role for percutaneous decompression as an alternative treatment prior to decompensative laparotomy.

Decompensative laparotomy is the gold standard for treatment of ACS. Restoration of volume status, restoration and correction of poor perfusion, and correction of hypothermia, acidosis, and coagulopathy are priorities during the acute phase of resuscitation. Decompression of the abdominal cavity may be performed at bedside if necessary; the surgical suite may be used when more complex procedures are needed. Decompressive laparotomy is followed by temporary abdominal closure, the selected method depending upon whether the abdominal wall fascial layer is left open or closed. When the abdominal wall fascia is closed, primary closure with a synthetic material or polytetrafluoroethylene is recommended. If the fascia is to be left open, the skin may be closed or left open. Mesh can be used for temporary abdominal closure, and is sutured to the skin or fascia and covered with moist sterile dressings, thus preserving the fascia for later definitive closure. Skin closure itself may be associated with increased intra-abdominal pressure, so care must be taken when selecting this option. Permanent abdominal closure is usually planned for a time after the acute phase of resuscitation, with primary closure of the fascia and then skin.

Scott et al. described the results of a retrospective review of 37 patients with open abdomens who underwent definitive abdominal closure, using a combination of vacuum pack, vacuum-assisted wound management, human acellular dermal matrix (HADM, Alloderm, Lifecell Corporation, Branchburg, NJ), and skin advancement (84). The mean duration of the open abdomen was 21.7 days (range 6–45). No major complications (intra-abdominal infections, fistulae, or failed graft) other than two superficial wound infections were reported, and all 37 patients survived (84).

What Are the Complications if the Abdominal Compartment Syndrome Is Not Diagnosed in a Timely Manner?

Multiple organ dysfunction results from prolonged intra-abdominal hypertension. Forced abdominal wall fascial closure should be avoided. Physiologic exhaustion can lead to multiple organ failure and death if ACS is allowed to progress. Prolonged bowel ischemia is associated with intestinal necrosis. Kinking of the bowel mesentery is associated with necrosis of the bowel, followed by intra-abdominal abscess. Respiratory failure and cardiovascular collapse will follow. Bowel torsion causes ischemia and can lead to necrosis. In this situation, delayed diagnosis may allow progression to diffuse peritonitis with the attendant large fluid resuscitation requirement associated to blood loss. Abdominal wall compliance will determine the degree of distention prior to development of ACS signs. Once the intra-abdominal pressure reaches 25 mm Hg, the major concerns are extensive ischemia and necrosis of the small bowel. Short bowel syndrome may result from radical resections of dead bowel; this will require evaluation of nutritional status to prevent malnutrition. Missed colonic injuries may be associated with diffuse peritonitis. In this situation, intestinal diversion is mandatory. Temporary abdominal closure requires the open technique; an occlusive dressing may be used to contain the intra-abdominal contents, along with a suction system composed of two drain catheters to remove the excessive fluid accumulation associated with ACS. Indirect measurement of pressures from the urinary bladder is important in order to prevent recurrent ACS.

TABLE 73.3
COMPONENTS OF NONSURGICAL MANAGEMENT OF THE ABDOMINAL COMPARTMENT SYNDROME

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastric decompression</td>
</tr>
<tr>
<td>Rectal enemas</td>
</tr>
<tr>
<td>Colonic prokinetic agents (neostigmine)</td>
</tr>
<tr>
<td>Continuous venovenous hemofiltration with aggressive ultrafiltration</td>
</tr>
<tr>
<td>Paralysis</td>
</tr>
<tr>
<td>Botulinum toxin into the internal anal sphincter</td>
</tr>
<tr>
<td>Paracentesis</td>
</tr>
<tr>
<td>Gastrointestinal prokinetic agents (cisapride, metoclopramide, domperidone, erythromycin)</td>
</tr>
<tr>
<td>Furosemide with or without use of human albumin 20% Sedation</td>
</tr>
<tr>
<td>Body positioning</td>
</tr>
</tbody>
</table>


PELVIC FR Actures

Patients who sustain injury secondary to blunt mechanisms, particularly in vehicular or pedestrian trauma, are at risk for pelvic fractures. These fractures often are indicative of a high-energy blunt impact, as the pelvic ring is an extremely stable bony structure; thus, pelvic fractures rarely occur in isolation (85). They are estimated to occur in about 9% of all patients who are injured via blunt trauma (86). While about 91% of these fractures are neither deforming nor displaced, 9% can be considered “severe” pelvic fractures, defined by a pelvic
Injury with substantial deformation and displacement (86). The so-called “nonsevere” pelvic fractures do not typically pose much risk to patients in and of themselves, are not generally associated with other injuries, and tend to be managed conservatively with rest, non-weight-bearing status, and bracing, depending on the specific injury. This section of the chapter will focus on the diagnosis and management of “severe” pelvic injuries, which are associated with injuries to abdominal or pelvic organs as well as life-threatening hemorrhage and hemodynamic instability, and carry a mortality of about 10% in all patients, and up to 80% when hemodynamic instability is seen (87–89).

**Clinical Suspicion**

As mentioned previously, patients involved in blunt traumas are at risk for pelvic fractures. As such, the diagnosis should be considered in any patient sustaining blunt trauma. Regarding specific mechanisms of injury, Demetriades et al. performed a retrospective review of 16,630 blunt trauma patients, and found that patients involved in motorcycle crashes, sustaining pedestrian injuries, falling from heights greater than 15 feet, and involved in automobile crashes represented the most likely groups of patients to suffer pelvic injuries, with patients in motorcycle crashes the most likely to have severe pelvic injuries (86). In the conscious patient, complaints of pelvic pain, pain on hip rotation, pain on pelvic compression, the presence of blood at the urethral meatus, and finding a perineal and/or scrotal hematoma have all been associated with pelvic fracture and warrant further investigation (90). Most importantly, though, pelvic fractures represent another potential “hidden” source of hemorrhage, as patients may bleed into the retroperitoneum; thus, a patient with an appropriate mechanism of injury and unexplained hypotension should have the diagnosis of pelvic fracture considered.

**Diagnosis**

In situations where clinical suspicion is raised due to mechanism or physical examination findings, radiologic imaging confirms the diagnosis. Advanced Trauma Life Support (ATLS) guidelines suggest that plain film radiographs should be performed in all trauma patients sustaining blunt torso trauma, regardless of mechanism (91). The absolute requirement for these films has been called into question by many authors, most recently Gonzalez et al. in Birmingham (90). In their prospective analysis of blunt trauma patients, they determined that physical examination in the trauma resuscitation room carried a greater sensitivity for pelvic injuries (93%) than did anteroposterior radiographs of the pelvis (87%).

With the advent of increasingly rapid computed tomography (CT), these scans are being routinely performed for patients with blunt trauma. Obaid et al. compared CT and plain films in a retrospective review, determining that CT scans are superior to plain films for the detection of pelvic fracture, although they determined that plain films maintain a role as a screening tool in the hemodynamically unstable patient, and may allow for early notification of interventional radiology of the need for embolization (92). In addition to being more sensitive than plain films for the detection of fracture alone, CT scans offer the advantage of identifying active hemorrhage at the site of pelvic fracture, in the form of a contrast “blush” on arterial phase imaging. This is discussed further in the subsequent section, as the finding of a blush has significant implications for management.

Based on the history of injury, physical exam, and radiologic findings, pelvic fractures may be classified by type, each with predictive value for subsequent management, morbidity, and mortality. Pennal et al. developed one of the initial classification systems for pelvic fractures, correlating them with particular vascular injury patterns: type 1, anteroposterior compression with transverse opening of the pelvic ring (open book fracture, risk of internal iliac artery lesions); type 2, lateral compression (risk of iliac vessel and retroperitoneal injuries); and type 3, vertical instability (risk of posterior structural lesions) (93). Burgess et al. at Maryland Shock Trauma reviewed their experience with 210 pelvic fracture patients, classifying them into groups based on the original classification system of Pennal; additionally, they added a group for patients with combined mechanical injury (94). In their series, they demonstrated that type I injuries predicted greater transfusion requirements (mean 14.8 units) and a mortality risk of 20%, while lateral compression injuries were associated with much lower use of blood products (mean 3.6 units) and a mortality of 7%. Furthermore, they indicated that no patient with an isolated pelvic fracture or a vertical shear injury in their series died. They developed a system of management based on these classifications, elements of which are found in the discussion on management below.

**Management**

Beyond the usual components of the trauma resuscitation, management of the patient with severe pelvic fracture is aimed at control of hemorrhage and fixation of fractures (Table 73.4).

A description of the orthopedic maneuvers and procedures for permanent fixation of pelvic fractures is beyond the scope of this chapter; thus, this section will focus on rapid measures for control of bleeding.

One of the first and fastest ways to gain control following pelvic fracture is through external compression of the pelvis. A simple, rapid method to achieve this end was proposed in 2002 by both Routt et al. and Simpson et al., in separate articles (95,96). They proposed circumferential wrapping of the pelvis with a bed sheet and clamping the sheet anteriorly. This is a widely available, inexpensive method for temporary control under these circumstances, and is the recommended method of the ATLS guidelines (91). To achieve a similar end, the authors utilize a commercially available pelvic circumferential compression device (“pelvic binder”) placed during trauma resuscitation. The pelvic binder has been shown in a prospective trial to be a safe and effective method for the management of pelvic fractures, particularly those of the “open book” type (97). Pneumatic antishock garments (PASGs) are a final method of temporarily applying external compression to the pelvis; however, they carry the disadvantages of being large, being not readily available, preventing lower extremity access, and being associated with worsened outcomes in patients with thoracic trauma (98).

While stopping blood loss is the earliest goal in the patient with pelvic fractures and hemodynamic instability, it should be...
### MANAGEMENT PEARLS IN ABDOMINAL COMPARTMENT SYNDROME

Early identification of intra-abdominal hypertension may prevent abdominal compartment syndrome.

| TABLE 73.4 |
| MANAGEMENT PEARLS IN ABDOMINAL COMPARTMENT SYNDROME |

<table>
<thead>
<tr>
<th>Hg</th>
<th>IAPP</th>
<th>T1: OSO</th>
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<tbody>
<tr>
<td><strong>Mean arterial pressure</strong> – Intra-abdominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intra-abdominal perfusion pressure (IAPP) goal is ≥60 mm</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hg</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intra-abdominal pressure – Intra-abdominal pressure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Forced abdominal wall fascial closure should be avoided.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pretreatment correction of hypothermia, acidosis, and coagulopathy is of utmost importance during the acute resuscitation phase.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Damage control surgery consists of control of hemorrhage and contamination and identification of injuries, utilizing an abbreviated laparotomy. Resuscitation is indicated with refractory hyperperfusion associated with ongoing resuscitation.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Increased intra-abdominal girth combined with high ventilatory peak airway pressures and oliguria are common manifestations of abdominal compartment syndrome. Oliguria is an early sign of abdominal compartment syndrome. Urinary bladder pressure monitoring is strongly recommended.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temporary abdominal closure is an essential component of the management of abdominal compartment syndrome. Permanent closure is considered during the postresuscitation phase, and deferred until after secondary resuscitation is completed.</strong></td>
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</tbody>
</table>

remembered that fixation is often one of the best ways to accomplish this, as restoration of anatomic alignment may stop bleeding from small veins and cancellous bone. An external fixator may be applied reasonably rapidly, particularly in the case of a posterior ring disruption, where a C-clamp may be used; fixations involving anterior disruptions may require the additional transport time as well as the conditions and resources of the operating room to be accomplished (85).

In cases of major vascular injury, surgical techniques including exploration and internal iliac artery ligation have not been shown to be effective; thus, they cannot be recommended (99,100). In cases of combined abdominal and pelvic injury, a damage control laparotomy with pelvic packing may provide a quick method for dealing with multiple injuries that include bleeding pelvic fractures. Additionally, preperitoneal and retroperitoneal packing have recently been receiving attention in the trauma literature (101,102). Of particular interest is the paper by Cothren et al., in which the authors retrospectively analyzed their series of 28 patients undergoing preperitoneal packing (102). They demonstrated that the procedure could be performed rapidly and decreased the need for emergent angiobolization. Additionally, they showed decreased transfusion requirements and a reduction in mortality secondary to these injuries. This method, while needing additional validation, should be strongly considered in situations where angiobolization is not immediately available for hemodynamically unstable patients with pelvic fractures.

Following the initial resuscitation of the patient with pelvic fractures, CT scanning will often be pursued as a diagnostic means. As previously mentioned, CT has shown excellent sensitivity for identification of arterial pelvic hemorrhage through the identification of a contrast “blush.” In cases where CT demonstrates a potential arterial source for bleeding, or in cases where this injury is suspected, arteriography with possible angiobolization typically represents the next step in management. These techniques involve the obtaining of arterial access, selective cannulation of the iliac vessels, and instillation of contrast dye with the intent to locate the bleeding source within the pelvis under fluoroscopic visualization. Upon identification of an actively bleeding site (noted by extravasation of contrast), embolization is performed through the injection of Gelfoam or coils, which occlude the bleeding artery. Angiobolization is extremely successful in the control of hemorrhage, and is currently considered the treatment of choice in pelvic fractures with hemodynamic instability where appropriately trained staff and the necessary equipment are available (85). It should be noted that there are complications particular to angiobolization that should be watched for in the postprocedural period. As with any percutaneous arterial access, access site injuries may occur; however, a number of authors have also pointed out the complications associated with the embolization itself, including gluteal, skin, bladder, and femoral head necrosis (85).

### DELAYED DIAGNOSIS

**Discussion**

Under ideal circumstances, the primary and secondary surveys allow for the identification of all injuries sustained by the trauma patient. Unfortunately, the evaluation of the critically injured patient does not always allow for the immediate identification of all injuries. Limitations in the examination of the patient due to mental status changes secondary to head trauma or intoxication as well as the presence of distracting injuries often make detection of these injuries difficult. Although rapid, high-quality imaging techniques are now widely used in trauma evaluations, some findings are sufficiently subtle to evade early recognition. Finally, some injuries simply do not manifest themselves in a meaningful way until time has passed and signs or symptoms are present. Some of these injuries were described in previous sections. This section highlights some commonly missed injuries, situations in which suspicion might be heightened for these injuries, and the role of the tertiary survey instrument in avoiding missed injuries.

### Commonly Missed Injuries

Musculoskeletal injuries are among the most commonly missed injuries in multisystem trauma patients. In a retrospective review of 111 multisystem trauma patients, Ward and Nunley noted that 6% of orthopedic injuries were not detected (103). They found that most injuries were eventually discovered on the basis of physical exam and plain film radiographs alone, and identified several risk factors for missed orthopedic injuries: significant multisystem trauma with another more readily apparent injury; post-trauma radiographic and inadequate significance being applied to minor signs and symptoms. Laasonen and Kivioja reported a similar phenomenon, with 4% of orthopedic injuries missed and similar risk factors noted, with the
significant addition of missed injuries on existing radiographs also implicated (104). Findings such as these prompted Mack-
erse et al. to recommend routine plain film screening to include the lower extremities in obtunded blunt trauma patients (105). At our own institution, we have noted missed musculoskeletal injuries in obese trauma patients. Physical examination of these patients can be difficult, even when the patient's sensorium is completely intact; we have thus begun to perform routine plain film extremity surveys in these patients in order to decrease the incidence of missed injuries.

Injuries involving retroperitoneal structures have a strong potential for presenting in a delayed fashion. While CT scan has allowed for early and ready detection of retroperitoneal hematomas, pancreatic and duodenal injuries can sometimes be difficult, if not impossible, to identify in the early moments following injury. Pancreatic injuries occur in less than 5% of blunt abdominal traumas; however, they carry with them substantial morbidity and mortality risks (106). Suspicion should be raised in cases where the victim sustained a blow to the central abdomen. Since pancreatic injuries rarely occur in isolation, injuries to surrounding solid organs and other structures should prompt consideration of pancreatic trauma. In the alert patient, exam findings are typically nonspecific, with vague abdominal pain, epigastric discomfort, nausea, vomiting, and fever commonly seen. Laboratory testing provides equally imprecise findings as an elevated amylase may hint at the diagnosis, but is not specific for pancreatic injury (107). Imaging may provide clues to the diagnosis; however, CT findings are often subtle, and may be delayed following injury (108). In the days that follow injury, the patient may progress to develop any number of other findings, including pancreatic, pancreatic leak secondary to a fracture, or a pancreatic pseudocyst. Early identification of the injury may help to guide the most appropriate management as there are no physical exam, laboratory, imaging findings that reliably make the diagnosis, the onus falls to the trauma and intensive care unit provider to take into account the mechanism and the soft findings that suggest the injury, and to maintain awareness of the possibility of pancreatic trauma as the patient's hospital course progresses.

Duodenal injuries resulting from blunt trauma are equally challenging to diagnose, and possess many of the same features of pancreatic injury. These uncommon injuries (they occur in less than 5% of blunt abdominal traumas [109]) often result from forces similar to those leading to pancreatic trauma, the most common mechanism being a blow to the central abdomen leading to compression of intra-abdominal contents against the spine. Duodenal tears have also been reported to result from deceleration injuries (110). As with pancreatic injuries, associated trauma is common, with concurrent liver injuries occurring most often. Physical exam is also similar to that seen in pancreatic injuries, with ambiguous abdominal pain being the most common symptom, and nausea, vomiting, and the development of progressively increasing tachycardia and fever also seen (109). Laboratory findings are once again nonspecific, with elevated amylase levels suggestive of, but not diagnostic for, duodenal injury. CT scan is a sensitive modality for detection of retroperitoneal air and extravasated oral contrast, both of which may be seen in duodenal injury, although neither is specific for this condition. Additionally, CT scan is able to detect duodenal wall thickening and hematoma formation, signs of injury that would require different management than a frank perforation. Progression of an undetected duodenal inj

jury with leakage into the retroperitoneum may either be walled off and contained or communicate with the peritoneal cavity, resulting in a life-threatening peritonitis (109). Once again, early diagnosis is often difficult with only soft findings pointing to the identification of a duodenal injury, and only maintenance of a high index of suspicion will allow the physician to make the diagnosis early and allow for the most appropriate management.

Jejunal or ileal injuries may go undetected because, as in the case of pancreatic or duodenal trauma, the findings may be subtle. In the recent EAST multi-institutional hollow viscus injury trial, small bowel injuries affected only 0.9% of blunt trauma victims; however, the authors noted significant increases in both morbidity (29% vs. 14%) and mortality (19% vs. 12%) when patients with small bowel injuries were compared to similar patients without them (111). As with pancreatic and duodenal injuries, physical examination is only of suggestive benefit, with abdominal pain, nausea, vomiting, and potentially signs and symptoms of peritonitis (in the case of a perforation) pointing to the diagnosis. CT scan may show unexplained free abdominal fluid, bowel wall thickening, or in the case of a perforation, free air or extravasated gastrointestinal contrast material. These findings are not always seen and CT scan is estimated to have a reasonable sensitivity of about 88% with a specificity of 99% (112). Malhotra et al. in Memphis were concerned about the grave prognosis that was previously reported by Fukhry in association with as little as an 8-hour delay in diagnosis of small bowel injury (113). In their review of patients with proven or suspected blunt bowel or mesenteric injury, the group in Memphis proposed an algorithm for management of patients with findings suggestive of these injuries (112). They found that hemodynamically stable patients with multiple CT findings suggestive of bowel or mesenteric injury showed a high likelihood of having such injuries, and should undergo exploratory laparotomy. They felt that the rarity of the injury and the lack of sensitivity of CT scan precluded laparatomy in patients with only one finding, but given the potentially devastating complications of a missed injury, suggested that diagnostic peritoneal lavage (DPL) be performed in this group of patients. They recommended that patients with positive microscopic, cell count, or biochemical criteria on DPL undergo exploratory laparotomy. We have adopted this approach at our institution and recommend it, with the additional caveat that we believe diagnostic laparoscopy is warranted in patients with equivocal findings on DPL.

The Role of the Tertiary Survey Instrument

As mentioned in the introductory section of this section, the primary and secondary surveys do not always allow for the identification of all injuries. In 1990, Enderson et al. reported their experience with the prospective performance of a formal trauma tertiary survey, finding that this simple step allows for the detection of missed injuries (114). It is notable that in their series, they performed the survey in the first 24 hours following injury. Janjua et al. followed this up with a prospective study demonstrating that tertiary survey done within 24 hours detected 56% of all missed injuries and 90% of all clinically significant missed injuries (115). Biff et al. described their experience following implementation of a formal tertiary survey form and policy at the Rhode Island Hospital, showing a
Chapter 73: Secondary and Tertiary Triage of the Trauma Patient

A decrease of 36% in missed injuries (116). In their discussion, they called attention to the fact that a limitation of their policy and practice was that many times, within 24 hours, patients were still in an altered mental state and at times were not yet ambulatory, and that this could potentially lead to missed injuries. They proposed that the tertiary survey be performed once within 24 hours and then once again in patients who were nonambulatory or comatose when these situations had subsided. It is the practice at our institution to follow this recommendation. An example of our Acute Care Surgery Service’s tertiary survey form is seen in Figures 73.4 and 73.5. At our institution, we take advantage of the tertiary survey instrument to review and record the patient’s mechanism of injury, medical history, physical examination findings, laboratory trends, final radiologist reads on imaging findings, the interventions that have been performed up to that point in time, and the patient’s immediate plan of care. We feel that this approach leads to a thorough evaluation that allows for an appropriate tailoring of care in the patient with medical comorbidities and minimizes missed injuries. Additionally, we find that it provides a succinct summary of the patient’s admission, with the benefit of a time lapse for review of key findings and interventions, to which all care providers may refer for patient information.

FIGURE 73.4. The tertiary survey instrument of the Acute Care Surgery Service of Shands Hospital at the University of Florida, Page 1.
### SHANDS at the University of Florida

**Trauma and Emergency Surgery**

**Tertiary Survey Form (page 2 of 2)**

<table>
<thead>
<tr>
<th>Consults / Interventions (include dates):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurosurgery:</td>
</tr>
<tr>
<td>Orthopaedics:</td>
</tr>
<tr>
<td>Plastics / ENT / OMFS:</td>
</tr>
<tr>
<td>Urology:</td>
</tr>
<tr>
<td>Others:</td>
</tr>
</tbody>
</table>

#### Radiology Findings (Please provide FINAL READS):

- Plain Films:
  - CXR:
  - Pelvis:
  - T/L/S Spine:
  - Extremities:
  - CT / MR:

- Chest:
- Abdomen / Pelvis:
- Other:
- Laboratory Trends:
- Plan:

**MD Signature:________________ MD:________ Date / Time:__________

**THE Attending:**

I have seen this patient with _____________________________ and agree with plan and assessment.

---

**FIGURE 73.5.** The tertiary survey instrument of the Acute Care Surgery Service of Shands Hospital at the University of Florida, Page 2.

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