IMMEDIATE CONCERNS

Patient Transport to the Intensive Care Unit

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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. 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, this unidirectional flow is highly desirable, but
Discussion and a sense of trust for the health care providers 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 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 for- getting 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 comprehen-sion 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., regarding the commonly performed procedures and I have had all my questions answered to my satisfaction.

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 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.

Consent for Commonly Performed Procedures in the Adult Critical Care Units

Date________   Time________

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......................................_____
Pulmonary Artery Catheter Placement......................_____
Central Venous Line Insertion.............................._____
Peripheral Venous Catheter................................._____
Sedation Maintenance or Procedural....................._____
Intubation & Mechanical Ventilation...................._____
Bronchoscopy......................................................_____
Chest Tube Insertion..........................................._____

Consent for Commonly Performed Procedures in the Adult Critical Care Units

Date________   Time________

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......................................_____
Pulmonary Artery Catheter Placement......................_____
Central Venous Line Insertion.............................._____
Peripheral Venous Catheter................................._____
Sedation Maintenance or Procedural....................._____
Intubation & Mechanical Ventilation...................._____
Bronchoscopy......................................................_____
Chest Tube Insertion..........................................._____

FIGURE 73.1. The "universal" intensive care unit consent of Shands Hospital at the University of Florida.
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 measurement 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 anesthetics, 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 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 followed by a securely applied pressure dressing will quell the hemorrhage. 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
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Schedule for Massive Transfusion Protocol
Shands at the University of Florida

<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></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>10</td>
<td>rFVIIa</td>
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<td>3</td>
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<td>rFVIIa</td>
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<td>6</td>
<td>10</td>
<td>4</td>
<td></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., a two (2)-hour time period).

- Adult Greater than 10 units
- 15-12 year old child Greater than or equal to 5 units
- 6-12 year old child Greater than or equal to 4 units
- 2-5 year old child Greater than or equal to 3 units
- 0-1 year old child Greater than or equal to 1 unit

*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.](image)

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 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 persistent 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 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.
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 SvO\textsubscript{2} 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 SvO\textsubscript{2}. 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 SvO\textsubscript{2} goal.

In a similar study with a slightly different design, Baur'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 end points in the experimental group included goals of resuscitation including oxygen consumption index (VO\textsubscript{2}I) of greater than 150 mL/min/m\textsuperscript{2} or oxygen delivery index (DO\textsubscript{2}I) of greater than 400 mL/min/m\textsuperscript{2}. 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 approach showed 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, DO\textsubscript{2}I, and VO\textsubscript{2}I. 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 (tcO\textsubscript{2}) and carbon dioxide (tCO\textsubscript{2}) 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 tcO\textsubscript{2} 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, tcO\textsubscript{2} to fraction of inspired oxygen ratio >200, DO\textsubscript{2}I >600, and VO\textsubscript{2}I >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 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.

Goal-directed Therapy: Other Considerations

Obviously, shock may result from any of a number of insults; thus, this issue has been examined in a number of settings, primarily in that of septic shock. In 2001, Rivers et al. released a landmark paper describing early goal-directed therapy in septic shock (26). In this randomized, controlled trial, in which patients were treated with 6 hours of goal-directed or standard resuscitation therapy in the emergency department, they demonstrated improvements in organ dysfunction and inhospital mortality. Despite their striking findings, and the findings of previous and subsequent authors, questions exist about the validity and applicability of the data, particularly when extrapolated to other settings (27). Judging by the ongoing debate in the literature at present, it is safe to say that no consensus has yet been reached on whether or not early goal-directed therapy is necessary in the resuscitation of the critically ill patient.

Another area of contention in the trauma literature for decades has been the use of crystalloid versus colloid resuscitation fluids. The Cochrane Library performed a recent meta-analysis on the randomized controlled studies covering this topic, and determined that there is no survival advantage to using colloid resuscitation fluids (albumin, hydroxyethyl starch, modified gelatin, or dextran) and thus concluded that at this time, there is no justification for their use outside of clinical trials (28). Despite this, debate continues on the subject, and there are ongoing trials evaluating this topic.

With regard to end points and the equipment utilized to measure them, there is again no true consensus. The use of pulmonary artery catheters to guide management is a particularly controversial one, particularly in light of studies such as that by Conners et al., which demonstrated an increased mortality in critically ill patients undergoing right heart catheterization (29). While authors such as Shoemaker et al. have attempted to address this issue, even they recognize the limitations of noninvasive monitoring (23). There are a number of methods and end points that may be used to monitor ongoing resuscitation, and these will be touched on briefly here.

Laboratory Testing

Lactate and base deficit are two levels commonly used to evaluate the adequacy of resuscitation. Elevated lactate levels have been correlated with both morbidity and mortality in critically ill patients, and both absolute levels and clearance of lactate are considered appropriate end points for use in resuscitation (30-33). Baseline lactate has been shown to be associated with volume of resuscitation fluid and blood following injury, and elevated levels have additionally been shown to correlate with increased mortality (30,34,35).

Right Heart Catheterization Levels

Values obtained through right heart catheterization are considered the “gold standard” physiologic measurements to that which noninvasive cardiovascular measurements are compared. The primary end point obtained through right heart catheterization is that referred to in the literature as DO₂/l, 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 DO₂/l as an indicator of resuscitation in the critically ill (20,21,23-25). 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 DO₂/l 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
Chapter 73: Secondary and Tertiary Triage of the Trauma Patient

Blunt cardiac injury (BCI) be classified according to descriptors of the specific abnormalities associated with the injury, thus the terms followed:

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, pneumomediastinum, 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, BCI patients are often in a state of altered consciousness. In this latter group of patients, the presence of refractory hypotension should suggest the possibility of BCI.

Diagnosis/Monitoring

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, S4, 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).

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.

Should the ECG and mechanism of injury heighten suspicion for a BCI, obtaining a troponin I level should be considered. Troponin I has been shown in BCI patients to have a sensitivity ranging from 23% to 100% and a specificity of 85% to 97% (47,57–59). In perhaps the most important look at this topic, Velmahos et al. reviewed a series of 333 BCI patients over a 2.5-year period, and found that in all cases, a normal admission ECG and troponin I followed by a normal ECG and troponin I at 8 hours completely ruled out BCI, and they suggested that in the absence of other injuries, patients with these findings could be discharged safely (60).

Formal echocardiography has been looked at by several authors in BCI (55,61–63). In each circumstance, the authors have noted that echocardiography has no role in the screening of the stable patient with suspected BCI. In the patient with hemodynamic instability, it is felt that transthoracic echocardiography may provide diagnostic information; however, transesophageal echocardiography offers improved images and evaluation of the aorta, making it of greater value (47,64,65).

Monitoring of the patient with diagnosed BCI is largely dependent on the type of injury sustained. In the patient with 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.

Management

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 Maenza et al. and Velmahos et al. found in their respective series that ECG and/or enzyme irregularities on admission and at subsequent points were more likely to predict cardiac complications (hypotension, arrhythmias, pump failure) and interventions during hospitalization (53,60). Thus, patients with these abnormalities should be observed for complications with management dependent upon the presenting symptoms.

Complex arrhythmia with BCI is the next most common injury pattern, and may consist of atrial dysrhythmia, ventricular dysrhythmia, or commotio cordis (myocardial concusison). 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...
EXTREMITY COMPARTMENT SYNDROME

Definition/Discussion

The upper and lower extremities are divided into several fascial compartments that contain the muscle, blood vessels, and nerves that supply the respective limbs. During traumatic injury, fluid (as a result of the combination of leaking capillaries and large volumes of resuscitation) or blood (as a result of direct injury and/or coagulopathy) may accumulate in these closed fascial spaces, leading to an increase in pressure within the compartment. This increased pressure causes impaired lymphatic, venous, and arterial flow, and may lead to nerve compression. This may lead to paresis, permanent nerve damage, and, if allowed to continue unchecked, ischemic injury and tissue necrosis in the affected extremity.

Clinical Suspicion

Extremity compartment syndrome should be considered in any patient who has presented with extremity trauma. McQueen et al. reported that compartment syndrome most commonly occurs in patients with an extremity fracture (usually of the tibial shaft or distal radius), followed by patients with soft tissue injuries without fracture (72). While compartment syndrome is most commonly associated with fracture within a closed space, an open fracture does not preclude the presence of a compartment syndrome. Suspicion should also be heightened in patients taking any anticoagulant medications (73). It must be remembered that while injury to the extremity often causes these injuries, at times therapeutic measures may exacerbate this condition with wraps and dressings, traction splinting, use of the l thigh position or abduction of the leg during surgery, or even intra medullary nailing in a tibial fracture repair all having been associated with the development of extremity compartment syndrome (73).

Diagnosis/Monitoring

Diagnosis of extremity compartment syndrome is primarily clinical, and requires a high index of suspicion. It is frequently suggested that the presence of the “six P’s” (pain, pulselessness, pallor, pressure, paresthesias, and paralysis) are the keys to diagnosis (73), although in the authors’ experience, this correlates better with acute arterial occlusion than compartment syndrome. Pain during passive range-of-motion exercises is often the first sign of a developing problem; unfortunately, this has clear limitations in the patient with mental status changes, and can be a limited finding. Pulselessness is found occasionally, although usually as a late finding once compartmental pressures have become great enough to overcome arterial pressure. An increase in compartment pressure is a potentially objective finding, as the extremity may feel tense and swollen, although it can often be difficult, particularly for the inexperienced examiner, to distinguish this from the edema that follows a significant traumatic injury to the affected extremity. Paresthesias are potentially ominous signs, as they may represent muscle or nerve ischemia; conversely, they may be only a manifestation of pain and are thus not reliable indicators of compartment syndrome (73). Additionally, as with pain, paresthesias cannot be assessed in the unconscious or sedated patient. Finally, paralysis is a late finding that is resultant from prolonged nerve ischemia or irreversible muscle damage.

Since the clinical diagnosis can sometimes be difficult and/or unclear, monitoring devices have been developed to evaluate intracompartmental pressures. Both slit catheter and side port needle techniques have been described for this purpose with equal efficacy and accuracy reported in the literature (74). Regardless of method utilized for measurement, it has been recommended that patients demonstrating a ΔP value of 20 mm Hg between measured compartment pressure and diastolic blood pressure should undergo fasciotomy (73).

Management

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...
A decompressive celiotomy is indicated in the presence of abdominal distention, hypercarbia, and high peak inspiratory pressures. This procedure may be performed either at bedside or in the operating room.}

The surgical technique performed for damage control is a continuum that includes primary resuscitation, damage control celiotomy, secondary resuscitation, and delayed reconstruction (76). Patients in extremis usually do not tolerate reconstruction. In summary, ACS is a surgical emergency that requires decision making at bedside or in the operating room.

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**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 measurements conducted 1 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 minimum of two standardized measurements conducted 1 to 6 hours apart.

Intra-abdominal hypertension is graded as described in Table 73.2.

**Definition/Discussion**

Abdominal compartment syndrome (ACS) occurs from increased intra-abdominal pressure. Richardson and Trinkle described elevated end-inspiratory pressures and hypoperfusion secondary to a low cardiac output (CO) associated with ACS (73). Impaired venous return and high peak inspiratory pressure with hypercarbia were present, causing hypoperfusion and severe pulmonary dysfunction. Early surgical decompression is mandatory, and a better outcome is associated with early detection. Release of the restrictive abdominal pressure will result in the correction of organ dysfunction. Oliguria is an early sign of ACS, but the most reliable clinical indicator is progressive failure of ventilation. A typical case of ACS has a peak inspiratory pressure in the range of 85 cm H2O with a rise in PaCO2. A decompressive celiotomy is indicated in the presence of abdominal distention, hypercarbia, and high peak inspiratory pressures. This procedure may be performed either at bedside or in the operating room.

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**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 by injecting 50 to 100 mL of sterile saline into the aspiration port of the Foley drainage tube. The catheter is then clamped distal to the aspiration port and a 16-gauge needle is used to connect a pressure transducer to the aspiration port of the catheter. The top of the symphysis pubis (or the midaxillary line) is used as the zero point on the supine patient.

For continuous, indirect intra-abdominal pressure measurement, a balloon-tipped catheter in the stomach or a continuous bladder irrigation method is recommended (Fig. 73.3). ACS is not seen as long as the intra-abdominal pressure is normal. The group at Denver Health Medical Center has proposed a grading system based on urinary bladder pressure measurements (77). A pressure of 25 mm Hg or higher is associated with organ dysfunction and considered clinical intra-abdominal hypertension. At or above this pressure, surgical decompression is justifiable.

The old saw “If it’s not in your differential, you can’t make the diagnosis” applies to ACS. A high index of suspicion is of utmost importance if ACS is to be prevented. Early identification of high-risk groups mandates early and aggressive monitoring of intra-abdominal compartment pressures in order to initiate appropriate treatment if needed. In the nonmonitored patient, clinical findings of elevated intra-abdominal pressure include an abnormal increase in abdominal girth associated with an increase in peak airway pressures and/or hypercarbia, increased central venous pressure (in euvolemic patients), and oliguria. In patients who are monitored with a urinary bladder catheter, early detection of intra-abdominal hypertension can direct aggressive treatment to prevent ACS. Indirect measurement of intra-abdominal pressure, through the monitoring of bladder pressure, is a very important tool that, after proper calibration, can provide vital information used to direct therapy. Urinary bladder pressures greater than 25 mm Hg in the high-risk patient are strongly associated with the presence of ACS and suggest the need for initiation of aggressive treatment to prevent clinical deterioration.

The inaugural World Conference on Abdominal Compartment Syndrome held in Australia in December 2004 produced consensus definitions as follows (78,79):

**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 measurements conducted 1 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 minimum of two standardized measurements conducted 1 to 6 hours apart.

Intra-abdominal hypertension is graded as described in Table 73.2.

Abdominal perfusion pressure—defined as mean arterial pressure minus intra-abdominal pressure—was compared with intra-abdominal pressure, arterial pH, base deficit, arterial lactate, and urinary output as an end point of resuscitation and predictor of survival (80). An abdominal perfusion pressure of 50 mm Hg was a potential end point for resuscitation in the patient with an elevated intra-abdominal pressure, and was superior to other end points listed in predicting survival for patients with intra-abdominal hypertension and ACS. The ACS was defined as the presence of an intra-abdominal pressure of 20 mm Hg or greater, with or without an abdominal perfusion pressure below 50 mm Hg, recorded by a minimum of three standardized measurements conducted 1 to 6 hours apart, and...
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 and peak inspiratory pressure at 24 hours postinjury 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.
in thermally injured patients (83). Of nine patients who de-
veloped intra-abdominal hypertension, five were successfully
treated with catheter decompression using a diagnostic peri-
toneal 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 per-
cutaneous decompression as an alternative treatment prior to
decompressive laparotomy.

Decompressive laparotomy is the gold standard for treat-
ment 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. Decompres-
sive 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 pre-
serving 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 ab-
dominal 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 defini-
tive 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 compi-
lcations (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 mesentry 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, de-
layed diagnosis may allow progression to diffuse peritonitis
with the attendant large fluid resuscitation requirement unas-
sociated to blood loss. Abdominal wall compliance will de-
terminate 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 nutri-
tional status to prevent malnutrition. Missed colonic injuries
may be associated with diffuse peritonitis. In this situation, in-
testinal 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.

### PELVIC FRATURES

#### Definition/Discussion

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

### TABLE 73.2

<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>
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<tr>
<td>IV</td>
<td>&gt;25</td>
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### TABLE 73.3

**COMPONENTS OF NONSURGICAL MANAGEMENT OF THE ABDOMINAL COMPARTMENT SYNDROME**

- Gastric decompression
- Rectal enemas
- Colonic prokinetic agents (neostigmine)
- Continuous venous hemofiltration with aggressive ultrafiltration
- Botulinum toxin into the internal anal sphincter
- Paracentesis
- Gastrointestinal prokinetic agents (cisapride, metoclopramide, dopaminone, erythromycin)
- Furosemide with or without use of human albumin 20%
- Sedation
- Body positioning

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 motocycle 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 analyses 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 computerized 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 injury); 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 Rourt 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 measure that have been utilized in the management of these injuries, although 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...
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 compression with Gelfoam or coils, which occlude the bleeding artery. Angiembolization 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 angiembolization that should be watched for in the post-procedural 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).

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 in the same extremity; physiologic instability; altered sensorium; quickly applied splints for a less serious injury; post-quality initial radiographs; 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-

ersie 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 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). Suspect 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 im-

precise findings as an elevated amylase may hint at the diag-

nosis, 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 symptoms, including intraperitoneal, pancreatic, and mesenteric injuries. Early identification of the injury may help to guide the most appropriate management. If there are no physical exam, lab-

oratory, or 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 sug-

gest 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 trauma) (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, asso-

ciated trauma is common, with concurrent liver injuries oc-
curring 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 de-
tection of retroperitoneal air and extravasated oral contrast, both of which may be seen in duodenal injury, although nei-

ther 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 in-

jury with leakage into the retroperitoneum may either be walled off and contained or communicate with the peritoneal cav-

ity, resulting in a life-threatening peritonitis (109). Once again, early diagnosis is often difficult with only soft findings point-
ing to the identification of a duodenal injury, and only mainte-

ance 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 sub-
tle. 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 duode-
nal injuries, physical examination is only of suggestive ben-

efit, 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 abdominofluid, 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 85% with a specificity of 99% (112). Malhotra et al. in Memphis were concerned about the grave prognosis that was previously re-

ported by Fakhry 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 man-

agement 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 laparo-
tomy in patients with only one finding, but given the potentially devastating complications of a missed injury, suggested that di-

agnostic peritoneal lavage (DPL) be performed in this group of patients. They recommended that patients with positive mi-

croscopic, 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 segment 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 for-
tormal 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 prospec-
tive study demonstrating that tertiary survey done within 24 hours detected 56% of all missed injuries and 90% of all clini-
cally significant missed injuries (115). Biff et al. described their experience following implementation of a formal tertiary sur-
vey form and policy at the Rhode Island Hospital, showing 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.

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Trauma and Emergency Surgery
Tertiary Survey Form (page 1 of 2)

Date:
Admission Date: Admission Time:
HPI Recap (MOI, Interventions, Hospital Course):
Past Med / Surg Hist:
Social Hist:

Physical Examination

VS:
T: P: BP: R:

GCS:
Eyes: Verbal: Motor:

HEENT:
Neck:
CV:
Resp / Chest:
Abd / Rectal:
GU:
Extremities:
Neuro (CN, Extremities):

Lacerations / Abrasions / Burns (Document Location / Size):

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

Trauma and Emergency Surgery
Tertiary Survey Form (page 2 of 2)

Consults / Interventions (include dates):

<table>
<thead>
<tr>
<th>Patient Name:</th>
<th>T/L/Spine:</th>
</tr>
</thead>
</table>

Neurosurgery:
Orthopaedics:
Plastics / ENT / OMFS:
Urology:
Others:

Radiology Findings (Please provide FINAL READ):

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.

References

Chapter 37: Secondary and Tertiary Triage of the Trauma Patient


Section VIII: The Surgical Patient


80. Cheatham ML, White MW, Sragove SG, et al. Abdominal perfusion pres-


82. Oda J, Ueyama M, Yamashita K, et al. Hypotonic lactic acidosis resus-


86. Demetriades D, Karaiskakis M, Toutouzas K, et al. Pelvic fractures: epi-


89. Goldberg RJ, Shuldberg SR, Garth M, et al. Major skeletal injuries in the

90. Gonzalez RP, Fried PQ, Bukhalo M. The utility of clinical examina-


92. Obaid AK, Barleben A, Porral D, et al. Utility of plain film pelvic radio-

93. Williams BK, Khandhar D, et al. The role of routine screening pelvic CT


97. Krus K, Mohr M, Ellis TJ, et al. Emergent stabilization of pelvic ring in-

98. Gonzalez RP, Fried PQ, Bukhalo M, et al. The utility of clinical examina-

99. Gonzalez RP, Fried PQ, Bukhalo M, et al. The utility of clinical examina-

100. Cheatham ML, White MW, Sragove SG, et al. Abdominal perfusion pres-

101. Smith WR, Moore EE, Obibon P, et al. Retroperitoneal packing as a re-

102. Cothren CC, Obibon PN, Moore EE, et al. Prophylactic pelvic packing

103. Ward WG, Nunley JA. Occult orthopaedic trauma in the multiply injured

104. Landman EM, Kirovski A. Delirium diagnosis of extremity injuries in patients

105. Mackersie RC, Shuckhelf SB, Gartin M, et al. Major skeletal injuries in the

106. Cirillo RL Jr, Koniaris LG. Detecting blunt pancreatic injuries.


108. Akhrass R, Kim K, Brandt C. Computed tomography: an unreliable indi-


111. Watts DD, Fakhry SM. Incidence of hollow viscus injury in blunt trauma: an

112. Akhrass R, Kim K, Brandt C. Computed tomography: an unreliable indi-


115. Janjua KJ, Sugrue M, Deane SA. Prospective evaluation of early missed

116. Incidence of hollow viscus injury in blunt trauma: an analysis from 275,177 trauma admissions from the Four multi-institutional trauma.


118. Akhrass R, Kim K, Brandt C. Computed tomography: an unreliable indi-


120. Biffl WL, Harrington DT, Cioffi WG. Implementation of a tertiary trauma

121. Jurkovich GJ, Carrico CJ. Pancreatic trauma.

122. Carrillo EH, Richardson JD, Miller FR. Evolution in the management of


124. Willi DD, Falkley SM. Incidence of hollow viscus injury in blunt trauma: an


127. Cheatham ML, White MW, Sragove SG, et al. Abdominal perfusion pres-


