AMERICAN HEALTH CONSULTANTS®

Evidence-Based Medicine for the ED

Trauma Reports

Enclosed in this issue: Reader survey

Vol. 3, No. 3

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

May/June 2002

The care of a trauma patient is demanding and requires adequate preparation, rapid access to equipment and resources, and skilled personnel. The system of trauma care is very important to provide rapid, thorough, and comprehensive care to each patient. Second in urgency only to the stabilization of the airway, shock in a trauma patient requires not only rapid stabilization, but also knowledge of pathophysiology and current trends and controversies associated with fluid resuscitation. This article will review methods for improving the efficiency of a trauma resuscitation, whether the physician practices in a high acuity, level I trauma center or a small, rural hospital. The authors also review the pathophysiology and stabilization of a trauma patient who presents in shock. The controversies associated with fluid resuscitation are presented, and future trends are discussed.

—The Editor

Initial Phase of Trauma Management and Fluid Resuscitation

Authors: **John P. Pryor, MD,** Assistant Professor of Surgery, Division of Traumatology and Surgical Critical Care, Department of Surgery, University of Pennsylvania School of Medicine, Philadelphia; **Richard J. Pryor, MD,** Clinical Assistant Instructor, Department of Emergency Medicine, Upstate Medical University, Syracuse, NY; **Perry W. Stafford, MD, FACS, FAAP, FCCM,** Director, Trauma and Surgical Critical Care; Assistant Professor of Pediatric Surgery, Department of Pediatric General and Thoracic Surgery, Children's Hospital of Philadelphia, PA.

Peer Reviewer: **Howard A. Werman, MD,** Associate Professor of Clinical Emergency Medicine, The Ohio State University College of Medicine and Public Health; Medical Director, MedFlight, Columbus, OH.

Introduction

Resuscitation, from the Latin *resuscitare*—to reanimate or revive, has many definitions, depending on what type of clinical system is considered. In trauma care, it refers to all of the diagnostic and therapeutic maneuvers that are used to treat patients who have been seriously injured. Physiologically, it defines the restoration of normal blood volume, blood pressure, and organ perfusion. On a cellular level, the term is used to describe successful restoration of the balance between oxygen utilization and cellular function. In all cases, resuscitation is considered the reversal of shock.

Orchestrating and managing a trauma resuscitation demands a thorough understanding of the physiology of shock, expert physical diagnosis ability, skill with complex procedures, ability to think rationally in chaotic situations, compassion, and fortitude. Those who become proficient in the process find no other situation in medicine more rewarding. However, obtaining the knowledge, learning the skills, and becoming confident in leading a resuscitation is demanding and often exhausting.

Thousands of resuscitations are undertaken every day in the United States, most in hospitals not designated as trauma centers. Despite years of refinement in the practice of trauma resuscita-

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

tion, there are many controversies about how best to manage patients who sustain significant trauma. Treatments that have been considered dogma, such as early and aggressive fluid administration for patients in shock, have been challenged recently. New technologies, such as ultrasound and high speed computed tomography (CT), have increased the ability to effectively diagnose and treat hemorrhagic shock. Advances in biochemistry, such as artificial blood substitutes, nearly are realities in modern day resuscitation. All of these aspects make trauma resuscitation an evolving and controversial arena for physicians.[1]

Conducting a Resuscitation

In the 1970s, regionalization of trauma care was proposed and the country's first trauma center was created at the University of Maryland. Regional trauma centers have allowed the field of trauma to mature, and have provided the research data that support the current management of multiple system trauma. However, a large percentage of trauma patients still are treated at hospitals that are not designated trauma centers. Therefore, it is important for all providers of emergency care to be facile in the techniques of resuscitation.

The Trauma Bay. The ideal location to perform a resuscitation is a specialized room in the emergency department (ED), set aside for trauma resuscitation. The most important requirement is that the room is large. The space must allow for several practitioners, x-ray machines, ventilators, ultrasound, procedure trays, and the stretcher. Procedure trays that are movable are most convenient. Trays should be set up with airway equipment, chest tube instruments, central venous line kit, and intravenous/blood-draw equipment. *(See Figure 1.)* The trays then can be moved toward or away from the stretcher as they are needed. The head of the stretcher should have an airway station stocked with suction, oxygen, intubation, and surgical airway supplies. The room should have at least two suction canisters (preferably more) that function well. Lighting is very important, and a dedicated operating room (OR) light should be placed above the stretcher to aid in complex procedures. A recorder table large enough for a flow sheet and a phone should be placed away from the patient. Extra supplies need to be readily available, either placed in open shelves or hung on hooks. Cabinets with doors are inconvenient and confusing, even if the contents of the cabinets are labeled. The supplies should be kept away from the patient, to reduce clutter and provide more room for the practitioners to work.

The physical location of the room within the hospital also is important, although this usually is dictated by the existing infrastructure. The room ideally is situated near the CT scanner and angiography room for fast transportation. Easy access to the OR and intensive care unit (ICU) also is important. If an elevator is needed to transport patients to one of these facilities, a key or call system should allow the trauma team immediate access to and control of the elevator. Efforts should be made to locate the room away from other patients in the ED, or to have a physical partition that will decrease the noise of the resuscitation. These considerations are most practical in centers that treat a significant number of trauma patients; however, the concepts are useful for any hospital ED.

Some institutions advocate direct transport of the most critical patients to an OR, avoiding time in the trauma resuscitation room altogether. This requires the hospital to have the resources of an immediately available OR and a triage system that accurately identifies patients who would benefit from bypassing the trauma bay. Several groups have shown that this management scheme may reduce time from arrival to operative incision, and may increase survival beyond predicted rates.[2] Patients who have benefited from direct transport include those with penetrating abdominal wounds, persistent hypotension with significant mechanisms of injury, and uncontrolled external hemorrhage.

Resuscitation Physicians. Depending on the hospital, and sometimes the time of day, trauma resuscitations are performed by different clinicians. Although trauma is a surgical specialty, resuscitation in the ED is a skill that is shared among surgery, anesthesia, and emergency medicine personnel. Among the specialties, there is variation in the training level of physicians participating and leading the effort. It is clear that the most efficient and well-run trauma systems take advantage of a collaborative effort by all specialties at all training levels. Systems and hospitals differ greatly in the way physicians are used in resuscitations. One center may have an on-call trauma team with in-house

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

Vice President/Group Publisher: Brenda Mooney
Editorial Group Head: Valerie Loner
Managing Editor: Allison Mechem
Marketing Manager: Schandale Kornegay

Periodical postage paid at Atlanta, GA. **POSTMASTER:** Send address changes to ***Trauma Reports***, P.O. Box 740059, Atlanta, GA 30374.

Accreditation

Trauma Reports'™ continuing education materials are sponsored and supervised by American Health Consultants. American Health Consultants designates this continuing education activity for up to 2.5 hours in Category 1 credit toward the AMA Physician's Recognition Award. Each physician should claim only those hours of credit that he/she actually spent in the educational activity.

This CME activity was planned and produced in accordance with the ACCME Essentials.

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

THOMSON
AMERICAN HEALTH CONSULTANTS

Subscriber Information

Customer Service: 1-800-688-2421

Customer Service E-Mail: customerservice@ahcpub.com
Editorial E-Mail: allison.mechem@ahcpub.com

World Wide Web page: http://www.ahcpub.com

Subscription Prices

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

For nonsubscribers, the price is $149.

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

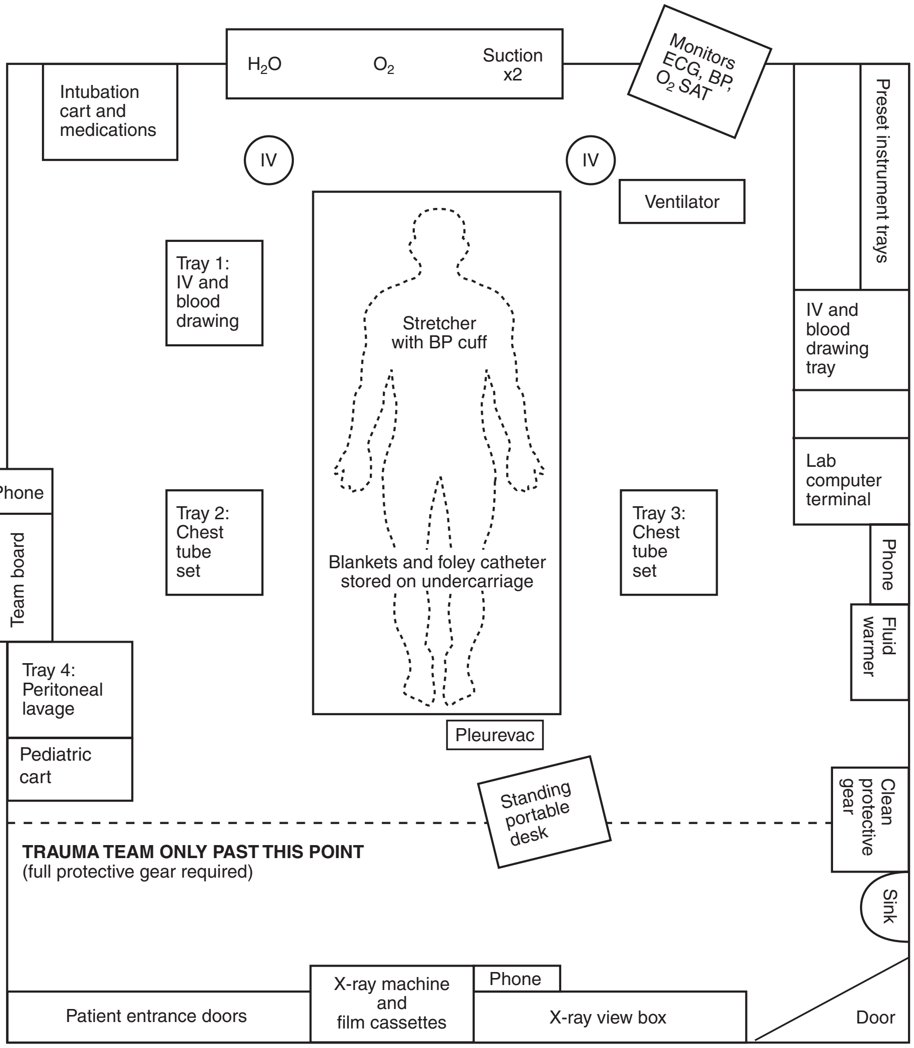
For Customer Service,

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

Conflict of Interest Disclosure

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

Figure 1. Layout of a Trauma Resuscitation Area



Used with permission from: Committee on Trauma, American College of Surgeons. *Resources for Optimal Care of the Injured Patient:1999*. Chicago:American College of Surgeons;117.

attending surgeon coverage, while another may have one emergency medicine attending as the resuscitator, with others called to the hospital as needed. There is some evidence that an in-house, on-call trauma surgeon significantly decreases time to complete diagnostic tests, time to the OR, and costs of resuscitation.[3] However, it has not been shown that the morbidity or mortality of trauma patients is changed when surgical residents perform the initial resuscitations with attending surgeons called in from home. Some institutions have developed a system in which the emergency medicine physicians perform the entire initial resuscitation, and only involve a surgeon when an operative procedure is needed. Most institutions, however, utilize a combination of residents from surgery and emergency medicine to make up the resuscitation team.

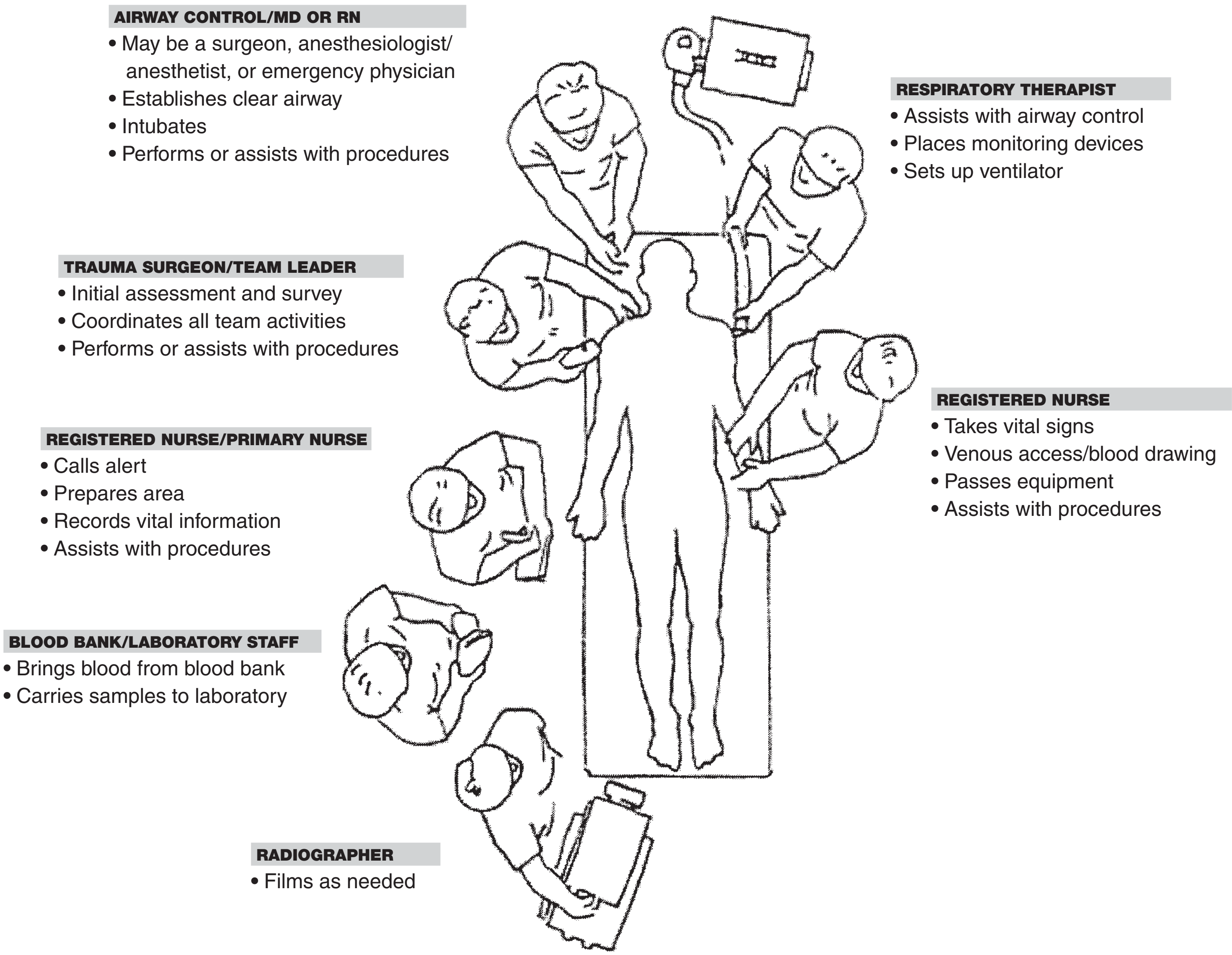
Paradigms of Resuscitation. There are two general types of resuscitation, depending on the location and personnel available to the patient. A *vertical resuscitation* completes diagnostic and therapeutic tasks in a step-by-step fashion. Vertical resuscitations often occur in hospitals with limited personnel resources, in multiple casualty incidences where clinicians are divided among patients, or when a patient arrives without notification and a single physician must initiate care. This form of resuscitation utilizes sequential examination and interventions by a single practitioner. For example, an emergency medicine physician in a community hospital would perform all assessments and procedures. Therefore, airway would be assessed, and if it was not secure, intubation would be performed before the breathing assessment could take place. Tasks are assigned to non-physicians according to their abilities. In many smaller hospitals, physician assistants or nurse practitioners may be able to perform procedures such as chest tube insertion. The physician team leader must direct the resuscitation, as well as participate directly in patient care. This is an organized and effective way to deliver care, but it is slow and burdensome to the practitioner.

A *horizontal resuscitation* is a collective effort by several practitioners working at the same time. It is the model most often seen in trauma centers where there are several physicians, nurses, and technologists available. *(See Figure 2 for one example.)* In this type of scenario, one physician can perform the primary and secondary assessments in their entirety. When an issue is found, such as a need for a chest tube, a second physician, if available, can perform the procedure as the first physician resumes the assessment. This allows multiple assessments and interventions to be accomplished at the same time. The advantage is that the initial diagnosis and treatment is accomplished quickly and completely. The major disadvantage is that the situation can get chaotic and unorganized if a team leader fails to assume control.

The Trauma Resuscitation Team. Success of a horizontal resuscitation depends on each member of the team understanding and executing his or her role while a clearly identified team leader keeps control and makes treatment decisions. The team consists of a command physician (team leader), airway practitioner, trauma nurse, recorder, chaplain, respiratory technologist, radiology technologist, and housekeeping staff. If available, additional physicians may perform assessments and procedures under the direction of the command physician. Each member of the team has directed responsibilities, and all are under the control of the command physician.

An identified command physician has been shown to enhance performance and improve efficiency of trauma resuscitation.[4] This physician can be a senior resident or an attending physician from either emergency medicine or surgery. The command

Figure 2. Positions and Roles of the Trauma Team Members During a Horizontal Resuscitation



Used with permission from: Committee on Trauma, American College of Surgeons. *Resources for Optimal Care of the Injured Patient:* Chicago: American College of Surgeons; 1999:119.

physician is positioned depending on the availability of other practitioners. If there are multiple practitioners to assist with the resuscitation, the command physician stands at the foot of the bed, away from the stretcher. If staffing permits, the team leader should not take on procedures or other tasks that will focus attention away from the entire process. Other duties of the command physician include communicating with the OR, radiology, and consulting physicians. This physician will make all decisions about what tests will be done and in what order, what fluids to run, when to transfuse blood, and which procedures to perform. In cases of multiple patients, the leader may need to oversee more than one patient at a time. This can be done if other capable physicians are performing the assessments and procedures on the multiple patients.

If a physician other than the team leader is available to act as assessment physician, he or she primarily is responsible for performing the primary and secondary surveys defined by the Advanced Trauma Life Support (ATLS) course of the American College of Surgeons. Often, a junior resident fills this role. The assessor will verbalize findings loudly so that the recorder, team leader, and team members can hear clearly. Initially, this physician stands to the patient's right, near the head. The team leader occasionally may direct certain parts of the exam to be done in a different order, such as getting a gross neurological exam before the patient is intubated for airway control. After completing the exam, the assessor becomes available to help with procedures or other tasks. The assessing physician has the responsibility of documenting his or her physical findings as a trauma admission physical exam.

The airway team is situated at the head of the bed and consists of one or two airway practitioners and a respiratory technologist. The practitioners may include a senior resident, trauma/critical care fellow, nurse anesthetist, attending emergency medicine physician, or an anesthesiologist. A second person is extremely helpful in cases of complicated airway management. The airway team, along with the assessing physician, will evaluate the airway for patency. If intubation is required, the airway team temporarily takes control of the resuscitation and directs other members of the team to position the patient, administer medications, and call for additional equipment, if necessary. In situations in which the airway is stable, the team will initiate oxygen therapy and elicit a history from the patient. Important aspects of the history include circumstances of the trauma, past medical history, past surgical history, medications, allergies, and when the patient last ate or drank. All of this information is relayed to the recorder and team leader.

If a procedure physician, other than the command physician, is available, he or she initially is positioned on the patient's left and away from the stretcher. Procedures are done at the discretion of the team leader, and include chest tube placement, central venous line insertion, splinting, and ultrasound exams. All procedures are done under the best possible sterile conditions, although OR conditions seldom are present in complex resuscitations. All procedures done by the procedure physician are recorded in the medical record as procedure notes.

One or two trauma nurses are positioned on either side of the patient. The initial responsibilities of the nurses include initiating electrocardiogram (ECG), oximetry, and blood pressure monitoring. Intravenous (IV) access is assessed quickly, and inadequate or missing IVs are converted to large-bore, free-flowing lines. The patient's clothes are removed and placed into a bag, and valuables are collected and catalogued. The trauma nurses are responsible for hanging fluids and setting rates, as determined by the team leader. They have the responsibility of checking blood and assuring that it is administered properly. They may assist in blood draws and administer medications, such as tetanus prophylaxis and antibiotics. Experienced trauma nurses seldom need much direction, and are adept at anticipating tasks and accomplishing them with a high skill level.

The recorder often is a nurse; however, in multiple patient scenarios, anyone who is familiar with the flow sheet can record. All aspects of the resuscitation are recorded to keep a complete record of assessments and treatments. In addition to vital signs and exam findings, the flow sheet should record decisions and events, such as "orthopedics contacted" or "patient vomited." This allows a clear and full picture of what happened during the resuscitation for later review. The team leader has a responsibility to review the trauma flow sheet for accuracy after the resuscitation is over.

A chaplain or social worker is an indispensable part of the trauma team. This person can be a minister from any denomination, and acts as a liaison between the family, patient, and the rest of the trauma team. The initial responsibility of the chaplain is to positively identify the patient and to make contact with the patient's family. The chaplain acts as the primary contact for the family and relays basic information to family members before they arrive at the hospital. Of course, the chaplain also has the role of spiritual leader for the patient and family, and frequently fills the role of counselor. A formal chaplain's note, including information about family contacts, is very helpful to physicians caring for a patient after he or she is transferred from the trauma bay.

A radiology technologist facile with the special requirements of trauma patients can streamline the radiographs taken in the bay. All members of the team should wear lead aprons under their gowns, so that radiographs may be taken while other tasks are completed. An overhead, movable x-ray machine is the fastest and most convenient way to perform radiographic procedures in the trauma bay; however, mobile machines can accomplish the same goals.

Housekeeping often is overlooked as a crucial part of the trauma team. Cleanliness is of the utmost importance, since the same stretcher and equipment may be used to treat several patients each day. Speed also is important, since a dirty bay cannot be used for the next trauma patient who arrives. A fast and efficient housekeeping team can avert many problems in busy centers.

Barrier Precautions. All personnel involved in the direct care of trauma patients must exercise universal precautions against body fluid exposure. The rate of HIV and hepatitis in trauma patients is significantly higher than in the general public, and has been reported to be as high as 19% in some centers.[5] Even in institutions with low rates of communicable disease, no one safely can determine who is and who is not infected with such pathogens. The standard barrier precautions include a hat, face mask, eyewear, gown, gloves, and shoe covers. Even in a busy center with a strict barrier precaution policy, one analysis showed only 89% of practitioners were compliant with the policy.[6] Unannounced trauma arrival is the situation that leads most often to a breach in compliance with precautions. Personnel should be instructed to take the time to put on protective gear, even if it means a one-minute delay in treating the patient.

Physiology of Hemorrhage and Shock

The goal of trauma resuscitation is to stabilize the patient and reverse shock. Hemorrhagic shock is caused by the loss of both circulating blood volume and oxygen-carrying capacity. The most common clinical etiologies are penetrating and blunt trauma, gastrointestinal bleeding, and obstetrical bleeding. Humans are able to compensate for significant traumatic hemorrhage through various neural and hormonal mechanisms. Modern advances in trauma care allow many patients to survive when the adaptive compensatory mechanisms become overwhelmed.[7]

Although there are many clinical causes of shock, the basic cellular derangement in all types involves an imbalance of oxygen utilization. Whenever cellular oxygen demand outweighs supply, both the cell and the organism are in shock. Cells that are not provided with enough oxygen shift from aerobic to anaerobic metabolism. Anaerobic metabolism is much less efficient in producing adenosine triphosphate (ATP) from fuel sources, but it can act to preserve cell function temporarily when there is inadequate oxygen supply.[8] The by-product of anaerobic metabolism is lactic acid, and accumulation of lactate will cause metabolic acidosis. Thus, the amount of lactate, or the severity of acidosis, can be used as a clinical marker of shock.

On a multicellular level, the definition of shock becomes more difficult because not all tissues and organs will experience the same amount of oxygen imbalance for a given clinical disturbance. Clinicians struggle daily to adequately define and monitor oxygen utilization on the cellular level and to correlate this physiology to useful clinical parameters and diagnostic tests.[9]

There are well-described responses to acute loss of circulating volume. The end result of these responses is that they systematically divert circulating volume away from non-vital organ systems so that blood volume is conserved for vital organ function. Acute hemorrhage causes decreased cardiac output and decreased pulse pressure. These changes are sensed by baroreceptors in the aortic arch and atrium. With a decrease in the circulating volume, neural reflexes cause an increased sympathetic outflow to the heart and other organs. The response is an increase in heart rate, vasoconstriction, and redistribution of blood flow away from certain non-vital organs such as the skin, gastrointestinal tract, and kidneys.

Concurrently, there is a multisystem hormonal response to acute hemorrhage. Corticotrophin-releasing hormone is stimulated directly, eventually leading to glucocorticoid and beta-endorphin release. Vasopressin from the posterior pituitary is released, causing water retention at the distal tubules. Renin is released by the juxtamedullary complex in response to decreased blood pressure, leading to increased aldosterone levels and, eventually, to sodium and water resorption. Hyperglycemia commonly is associated with acute hemorrhage. This is due to a glucagon- and growth hormone-induced increase in gluconeogenesis and glycogenolysis. Circulating catecholamines relatively inhibit insulin release and activity, leading to increased plasma glucose.

In addition to these global changes, there are many organ-specific responses. The brain has remarkable autoregulation that keeps cerebral blood flow constant over a wide range of systemic mean arterial blood pressures. The kidneys can tolerate a 90% decrease in total blood flow for short periods of time. With significant decreases in circulatory volume, intestinal blood flow is reduced dramatically by splanchnic vasoconstriction. Early and appropriate resuscitation may avert damage done to individual organs as adaptive mechanisms act to preserve the organism.

The physiologic aim in trauma resuscitation is to stabilize or reverse these physiologic derangements in patients who are in shock. This is accomplished by arresting ongoing hemorrhage, restoring circulating volume, providing oxygen-carrying capacity, and correcting other pathology that ultimately interferes with oxygen delivery (i.e., tension pneumothorax, pericardial tamponade).

Resuscitation Fluid

It perhaps is obvious that the fluid of choice for patients in hemorrhagic shock is blood. However, blood and blood products are not available in the field, and often not during the immediate phase of resuscitation. In types of shock other than hemorrhagic (e.g., septic shock), the patient's hemoglobin level may be even higher than normal, disqualifying blood as an adequate resuscitation fluid. In the absence of blood, there is controversy about what type of substitute fluid should be given, how it should be given, and how much should be used. New technologies and advances in the field of artificial blood have delivered some potential products that may be viable as blood substitutes in the future.[10]

Colloid vs. Crystalloid. Determining the optimal replacement fluid for patients in shock has been controversial since 1918, when fluid resuscitation first was reported to improve outcome in patients with hypovolemia.[11] Physicians realized early on that adequate resuscitation from hemorrhagic shock required the restoration of both circulating volume and oxygen-carrying capacity in the form of red blood cells. Much of the early research demonstrated the improvement in survival after hemorrhage when animals were resuscitated with both lactated Ringer's solution and blood.

During the time of the Vietnam War, complications of resuscitation—most notably, pulmonary dysfunction and renal failure—were appreciated. Many investigators began to search for a resuscitation fluid that could provide intravascular volume while limiting the accumulation of water in the interstitium, especially the lungs. Human albumin was a logical empiric choice, since it provided the intravascular space with oncotic pressure and did not readily cross the capillary membrane. Indeed, early animal studies showed that it remained in the vascular space, raised oncotic pressure, and even improved survival after hemorrhagic shock in some animal studies.[12] Human studies showed that exogenous administration increased serum albumin concentration and increased the oncotic pressure in the blood. Although these finding were encouraging, the effects of albumin were shown to be reversed completely 24 hours after administration.[13] More concerning, patients resuscitated with colloid after major trauma had a worse clinical course, remained on the ventilator longer, and had significantly worse intrapulmonary shunt than those who received crystalloid infusion.[14] Subsequent research has failed to determine if colloid is superior or inferior to crystalloid resuscitation in patients with hemorrhagic shock in regard to survival, pulmonary complications, and resuscitative time.

A large, evidence-based review of more than 82 studies comparing colloid to crystalloid resuscitation recently was reported by a group at McMaster University.[15] The meta-analysis revealed no overall difference in mortality, pulmonary edema, or length of stay between patients resuscitated with primarily colloid vs. crystalloid solutions. In a subgroup analysis, trauma patients who were resuscitated with colloid had a slightly increased relative risk of death, although with a poor confidence interval. The authors conclude that to show definitively a significant difference in mortality between the treatments, a randomized, prospective trial would have to include more than 9000 patients. Based on this and other available evidence, colloid resuscitation does not confer any benefit over crystalloid in hemorrhagic resuscitation. In addition, it does have certain disadvantages. It is a human blood product and is capable of transmitting infectious agents, although the risk is relatively small. It is expensive compared to lactated Ringer's solution, and has a limited shelf life. Therefore, colloid resuscitation cannot be recommended for routine use in the resuscitation of patients with hemorrhagic shock.

Blood. Most blood banks in the United States no longer provide whole blood for transfusion. Donated whole blood is separated into packed red blood cells (PRBCs) and plasma. Plasma from several donors is used to pool platelets, cryoprecipitate, and other special products, such as concentrated factor VIII.

Blood typing is the act of determining the antigens—A, B, or O—that are present on the cell surfaces of the red blood cells of the specimen. Blood type A, therefore, designates the specimen as having type A antigens on the cell surface. A second major antigen is the Rhesus (Rh) factor. Rh incompatibility is much less severe than incompatibility of ABO antigens. The major morbidity of Rh incompatibility is when an Rh-negative, pregnant woman is induced to develop Rh antibodies by exposure to Rh-positive blood. These induced antibodies will not have an effect on the patient, but may cross the placenta during pregnancy and result in a lysis syndrome of the fetal cells if the fetus is Rh-positive.

Although ABO and Rh represent the major antigens, they are only a few of the great number and variety of antigens that may be present on blood cell surfaces. To avoid incompatibility reaction of these minor antigens, blood from specific donors and recipients is mixed to determine if minor incompatibility exists; this is called a crossmatch.

The safest transfusion, and the one that is of least risk to the recipient, is when blood is typed for major antigens and crossmatched for minor antigens. This process can take more than an hour to perform. For patients who need immediate resuscitation for severe trauma, blood must be available before a formal type and crossmatch can be done. For this purpose, banked type O, Rh-negative blood is kept for immediate use. Men can receive Rh-positive blood without significant risk, since Rh incompatibility is relatively minor in males. Of course, type O blood contains A and B antibodies, which can react against the recipient's native cells. This reaction generally is not clinically relevant unless the amount of type O blood transfused is greater than four units within a short period of time. As soon as possible, type-specific, crossmatched blood should be exchanged for O-negative blood for transfusing. This illustrates the importance of sending a blood sample for type and crossmatch soon after the patient arrives in the resuscitation area.

Transfusion Triggers. The decision to transfuse blood is made after consideration of the mechanism of injury and the patient's hemodynamic status, response to crystalloid infusion, and premorbid status. In general, all trauma patients in shock should first receive crystalloid infusion (up to two liters).[16] Most often, this is administered in the field, and the physiologic response to the fluid can be assessed. If hemodynamic instability continues and there is significant blood loss, transfusion is begun immediately. In adults, two units of type O-negative blood are transfused wide open, preferably through a fluid warmer. Women of childbearing age should receive Rh-negative blood, whereas men may receive Rh-positive blood. A sample is sent concomitantly for typing and crossmatching. After each transfusion, the clinical situation is reassessed. Ongoing blood loss will necessitate continuous replacement with blood and crystalloid.

Patients who are not acutely exsanguinating, but have an anemia secondary to blood loss, also must be evaluated with special concern for their premorbid medical status. Several large studies have refuted the idea that there is a threshold hemoglobin or hematocrit that should prompt transfusion in the stable patient.[17,18] One recent large, randomized, multicenter study showed that receiving transfusions to a hemoglobin threshold of 9 g/dL conferred no physiologic or clinical benefit to patients when compared to those who were maintained at 7 g/dL.[19] In some groups, such as young patients with less severe illness (Acute Physiology and Chronic Health Evaluation [APACHE II] scores < 20), the mortality was higher in the group that was maintained at 9 g/dL. Other groups of patients, specifically ones with acute myocardial infarction and unstable angina, showed some benefit from maintaining a transfusion threshold of 9 g/dL. This study is the most definitive evidence that no single number is a universal transfusion trigger for patients with euvolemic anemia.

Some patients may require a large amount of transfusion in a relatively short period of time. Frequently, these patients can stress the capabilities of the hospital and area blood banks. Patients with massive transfusions are at higher risk of dying from their injuries. Independent predictors of mortality in these situations include persistent hypotension, inotrope requirement intra-operatively, and the need for aortic cross-clamping. However, the amount of transfused units has been shown not to be an independent predictor of a bad outcome, and the need for massive resuscitation cannot be used as an indicator to discontinue care.[20]

Plasma, Platelets, and Other Factors. Partitioning blood into cells and products increases efficiency and allows for the greatest benefit for the most patients from the donated pool. However, in trauma, the ideal blood product would be whole, unfractionated blood. This is due to the unique situation in trauma in which the patient requires not only volume and red cell mass, but also coagulation factors. Therefore, during large volume transfusions of PRBCs, decisions must be made as to which other blood products are to be given. Traditionally, patients were given fresh frozen plasma (FFP) and blood in a fixed ratio of two units FFP for every 4-6 units of PRBCs. Although this is a good estimate, the need for continued transfusion of plasma is determined by the clinical situation. Patients with ongoing bleeding and an elevated prothrombin time (PT) should receive additional FFP transfusions. Those without persistent bleeding do not necessarily need to have an abnormal PT corrected. Often, the limiting factor in following laboratory values for assessment of coagulopathy is the delay in getting results from the lab.

Platelets are pooled from several donors to form one unit. This unit often includes platelets from six donors; hence, it is referred to as a "six-pack" or "super pack." Platelets are suspended in plasma and, therefore, contain a small amount of other coagulation factors in addition to the cells. Transfusion triggers for platelets have been abandoned, along with thresholds for red cell transfusion. Platelet counts below $100/mm^3$ are common in severe trauma, and only patients with ongoing bleeding are candidates for transfusion.

Cell-saver Techniques. Autologous blood that can be collected and re-infused provides the best physiologic fluid resuscitation. Several "cell-saver" techniques have been developed to recycle lost blood. A cell-saver device, set up and managed by a certified perfusionist, collects blood through a suction device, admixes with heparin, washes the cells, and allows reinfusion. Large amounts of lost blood can be salvaged in this manner. In addition to providing whole blood and avoiding the risks of donated blood, salvaging autologous blood significantly decreases the cost of resuscitation by avoiding the use of expensive banked blood.[21] Cell-salvaging techniques also can be applied to situations in which the formal cell-saver apparatus is not available. Modification of chest tube collection devices has allowed collection and re-infusion of blood from hemothoraces to be performed at the bedside, without the need for cell-washing and treatment devices.

Hypertonic Saline. Hypertonic saline is a 7% NaCl solution that often is combined with dextran to form a hyperosmolar fluid used for resuscitation. The hypertonicity draws interstitial fluid into the vascular space, causing the effective fluid accumulation in the vessels to be greater than the volume of saline injected. Since saline is freely diffusable, the effect is transient unless a large, non-diffusable molecule, such as dextran 70, is added to maintain oncotic pressure within the lumen.[22] Hypertonic saline (7%)-dextran 70 (HSD) has been used clinically in situations in which large volumes of resuscitation fluid are not available or desirable.[23] Such situations include prehospital resuscitation, combat zones, pediatric resuscitation, and in patients with concomitant severe head injuries. However, there has been no conclusive evidence that hypertonic saline offers any short- or long-term benefit over standard crystalloid resuscitation. A role for hypertonic saline may exist in patients with shock and concomitant head injury. One group has shown that survival was better in this patient population when HSD was used instead of normal saline in the prehospital phase of resuscitation.[24] Further trials are needed to confirm HSD as a standard treatment option.

Delayed Fluid Resuscitation. There is some evidence that over-aggressive fluid resuscitation may be detrimental, especially in patients who have penetrating abdominal or thoracic injury. Animal studies suggest that there may be two stages of bleeding in penetrating injury. The first acute stage of bleeding occurs when the missile or knife disrupts a vessel. With hemorrhage, arterial blood pressure decreases, a clot begins to form at the arterotomy, and the arterial wall goes into spasm. This leads to a significant decrease (or even complete cessation) of bleeding from the site.[25] Aggressive resuscitation with non-blood fluids will increase the arterial pressure, and thereby disrupt the clot that has formed at the bleeding site.[26] There also is evidence that crystalloid resuscitation will dilute clotting factors and lower viscosity, leading to further leaking around the vessel injury. These factors lead to a secondary bleed that some investigators suggest is the cause of significant morbidity and mortality in patients with this type of injury. In 1994, one group reported a prospective, randomized trial that compared immediate vs. delayed resuscitation for patients with penetrating torso trauma.[27] Patients who received no prehospital resuscitation, followed by delayed hospital resuscitation, had an improved mortality over patients who received standard care. The numbers of postoperative complications, such as respiratory failure and renal failure, also were significantly less. Although there have been many criticisms of this larger study, it illustrates that there may be real complications with large volumes of crystalloid resuscitation for trauma patients. The American College of Surgeons recommendations for trauma resuscitation have not changed since the 1994 report, and initial infusion of lactated Ringer's or normal saline remains the standard of care as the initial treatment of hemorrhagic shock.[28]

Blood Substitutes. An oxygen-carrying, oncotic, non-toxic, non-infectious fluid that is abundantly available, cheap, has an indefinite shelf life, and is easy to use always has been desired. The early attempts were to infuse a hemoglobin solution, referred to as "stromal free hemoglobin." Although the solution effectively carried oxygen, it had several major problems. Free hemoglobin is a potent scavenger of nitric oxide (NO) and causes significant vasoconstriction. In addition, the solutions increase the production of toxic oxygen metabolites, resulting in neurotoxicity and renal failure.[29,30]

Modifications of the free hemoglobin have resulted in several hemoglobin-based, oxygen-carrying compounds (HBOCs) that someday may overcome the problems with stromal free hemoglobin.[31] Biochemical schemes to decrease the NO scavenging properties include "hiding" the reactive hemoglobin moiety by polynitroxylation (PN), cross-linking molecules with diaspirin (DCLHb), and polymerizing several molecules together (poly-Hb).[32] Currently, some of these products are being used in clinical trials, although all continue to have some clinical limitations.[33] Two recent trials using HBOCs for acute resuscitation of trauma patients were conducted. A group from the University of Colorado has used a polymerized hemoglobin, poly SFH-P, in patients requiring emergent blood transfusion for trauma or emergent surgery. Thirty-nine patients received more than six units of poly SFH-P, with a maintenance of the circulating hemoglobin level despite significantly decreasing red cell mass. Oxygenation and oxygen delivery also were preserved. There were no deaths in this series, and there was a conspicuous lack of side effects such as vasoconstriction or renal dysfunction.[34] Thus, a viable blood substitute with minimal clinical side effects soon may be practical. At present, however, such agents are used only in clinical trials.

Endpoints of Resuscitation

Control of hemorrhage, restoration of adequate circulation, and reversal of shock are the goals of resuscitation. Determining exactly when these have been accomplished sometimes is difficult. Clinical indicators of adequate resuscitation include measures of end organ perfusion. However, these clinical markers can be misleading, and various biochemical indices now are being used to determine when adequate tissue perfusion has been achieved.

Traditionally, clinical measures such as heart rate, blood pressure, and urinary output have been used to judge reversal of shock. Several studies have demonstrated that even with return of normal vitals signs, tissue oxygen imbalance can continue.[35] This is a state of compensated shock, which is common in young, otherwise healthy patients. The potential consequence of prolonged tissue under-perfusion is systemic inflammatory response syndrome, adult respiratory distress syndrome, and multiple organ failure. Therefore, there is a need to assess the reversal of shock on a cellular basis.

Several laboratory methods for assessing cellular oxygen balance have been utilized, including base deficit, lactate level, and mucosal pH monitoring.[36] Base deficit is an indirect measure of lactate production and is a fast, reliable indicator of shock. Several groups have shown that both the degree of base deficit and the time it takes to resolve correlate with the degree of shock.[37] One researcher showed that a base deficit of more than -15 in a patient younger than age 55 without a head injury was a significant marker for mortality after trauma.[38] Others have shown that the persistence or worsening of a base deficit is the best predictor of continued hemorrhage or ongoing shock.[39]

Since the base deficit is a calculated number, it is prone to errors in interpretation. Although lactic acidosis is the most common cause, other conditions can cause an increased base deficit. Hyperchloremic acidosis may result from over-resuscitation with normal saline, secondary to a loss of bicarbonate in the renal tubules. This results in an anion gap acidosis that is not caused by increased lactate production. Thus, it often is helpful to measure the amount of lactate directly instead of relying on the calculated base deficit. The lactate level in trauma patients has been shown to correlate with the depth of shock and to predict mortality.[40] Specifically, it has been shown that patients who have a normal lactate level within 48 hours of injury are much more likely to survive than those who have a persistent lactic acidosis.[41] Therefore, lactate is a good measure of the reversal of shock in the acute period. Lactate levels should be assessed at admission and every 6-12 hours during the acute phase of resuscitation.

Another method for measuring specific tissue perfusion is gastric tonometry. The pHi is the measured pH of the gastric mucosa. This is done clinically with a balloon sensor that is placed into the stomach in a manner similar to a nasogastric tube.[42] Gastric pH falls rapidly and in proportion to splanchnic under-perfusion, and is a very sensitive marker of ongoing oxygen imbalance at the tissue level. One group has used the pHi as an end point of resuscitation of trauma patients, using pHi greater than 7.3 as a marker for adequate tissue perfusion.[42] Although the technique and technology are available, no clear advantage has been shown for using pHi compared to analyzing more simple endpoints, such as lactate determination.

Determining when resuscitative efforts have been successful includes a clinical and biochemical assessment. Patients with stabilizing blood pressure and heart rate, adequate urine output, and appropriate mental status are believed to be clinically resuscitated from shock. Measurement of the base deficit and lactate levels will unveil ongoing tissue under-perfusion in patients with compensated shock. Assessing the trend of the base deficit and lactate level can help predict the risk of mortality in patients with significant trauma. New technologies, although encouraging, currently show little benefit over other, more traditional measures of organ perfusion.

Special Situations

Closed Head Injury. Hemorrhagic shock with concomitant closed head injury (CHI) portends a poor prognosis. One of the worst prognostic indicators for recovery after CHI is significant and persistent hypotension. Treatment of the CHI in these situations is aimed at restoring blood pressure, controlling bleeding, and assuring adequate cerebral perfusion pressure (CPP). When faced with the dilemma of CHI and persistent hypotension, diagnosis and treatment of the hemorrhage always takes precedence. Therefore, an unstable patient with evidence of intra-abdominal bleeding and a severe CHI would be taken directly to the OR for exploratory laparotomy, deferring the head CT scan until after bleeding is controlled and circulating blood volume is restored. A secondary concern is cerebral swelling and increasing intracranial bleeding. Although these conditions may be exacerbated by aggressive fluid resuscitation, adequate volume should not be withheld in patients who are in shock. Some have advocated using hypertonic saline in these patients, to provide adequate vascular volume while limiting the excess water administration. One prospective, randomized trial found that hypertonic saline was successful in providing volume while controlling intracranial pressure.[43]

Spinal Cord Injury. Spinal cord injury may superimpose neurologic shock onto hemorrhagic shock. Unstable patients with a known spinal cord injury first must be treated as if the hemodynamic instability is secondary to blood loss. Paraplegia or tetraplegia can impede the diagnosis of abdominal injury significantly by masking physical exam findings. The treatment for both types of shock is aggressive fluid administration, and this should be started on arrival. If ongoing bleeding eventually is excluded, and the patient is felt to have isolated neurologic shock, then vasopressors are indicated after adequate volume loading. Patients with neurologic shock are vasodilated inappropriately and often bradycardic due to a loss of sympathetic tone. Dopamine is the drug of choice, because it will cause vasoconstriction, increased chronotropy, and increased inotropy. Phenylephrine, a pure alpha agonist, also may be added to counteract the severe vasodilation.

The Elderly Patient. Although it is true that elderly patients have less physiologic reserve, more premorbid conditions, and less ability to compensate for injury, it is not true that age alone predicts morbidity and mortality in trauma. Several physiologic parameters are compromised in the older patient, including vascular compliance, myocardial reserve, and bone strength.[44] However, it has been shown that the elderly can respond to resuscitation after serious insults, and that age alone should not be used as marker for determining futile care.[45]

Initial management of the elderly is the same as for younger patients. Early determination of premorbid conditions, medications, and previous surgery is more urgent than usual. Heart disease is the leading premorbid condition that puts elderly patients at higher risk for complications following even minor trauma. A diligent search for a history of myocardial infarction or unstable angina may explain early hemodynamic instability in the face of trivial injury. The use of beta-blockers is widespread, and this may inhibit the patient from developing an appropriate tachycardia after injury. Coumadin, aspirin, and anti-platelet drugs are some of the many medications that cause these patients to be anticoagulated at the time of injury, putting them at risk for significant bleeding complications.[46] All elderly patients who arrive unresponsive are assumed to be taking such medications until laboratory confirmation, or until an adequate accurate history is found.

The Pediatric Patient. Pediatric patients initially are treated in the same manner as adult patients in regard to primary and secondary assessments and interventions. The difference is the child's physiological response to injury and the anatomical and clinical differences in treating a pediatric patient. Children have certain characteristics that make trauma resuscitation more difficult. First, communication is not always possible to the extent that it is with an adult patient. The physical exam findings become more important, and the clinician relies more on objective signs of injury than on chief complaints. The blood volume of children obviously is less, predisposing them to accelerated exsanguination. The relatively large body surface area contributes to rapid heat loss during resuscitation. Technical procedures can be more difficult in the child, especially venous access and endotracheal intubation.

Perhaps the most significant difference between adult and pediatric blunt trauma is that the vast majority of pediatric patients can be resuscitated and ultimately treated non-operatively. Whereas quick decisions are made about whether to operate immediately on adults, pediatric patients very rarely will need an emergent procedure. Blunt injuries to the spleen, liver, kidney, and pancreas, which in the past mandated surgery, now are being treated non-operatively with great success.[47] Currently, the diagnostic test of choice is CT scan, which not only will identify injuries, but also classify them. All grades of liver, spleen, and kidney injuries can be managed non-operatively, depending on the hemodynamic stability and the patient's physiologic response to resuscitation. Pediatric surgeons often will transfuse up to 40 cc/kg of blood products in an effort to stabilize children before reverting to laparotomy for even severe injury, because exploration has been shown to increase blood loss and transfusion requirement over successful, non-operative management. Therefore, children with all grades of injury should be treated based on their physiologic response to resuscitation. If the hemodynamics stabilize after transfusion, observation continues in the ICU. If the child fails and continues to be unstable, laparotomy is indicated.[48] In penetrating trauma this is not true, and children are similar to adults in the indications and need for prompt surgery.

Conclusion

The most critical aspect of trauma resuscitation is preparation. A specified room and easily accessible equipment and resources are critical factors for the smooth functioning of a trauma team, even in the most rural setting. Assigned responsibilities and easy access to equipment required for procedures facilitate an efficiently run trauma resuscitation. Knowledge of the acute presentation of patients in shock and techniques for rapid resuscitation enables the physician to confidently facilitate the rapid stabilization of a trauma patient. In addition, knowledge of the controversies and alternatives for fluid resuscitation guide the critical decisions that must be made early in the patient's clinical course.

References

1. Henry S, Scalea TM. Resuscitation in the new millennium. *Surg Clin North Am* 1999;79:1259-1267.
2. Fischer RP, Jelense S, Perry JF Jr. Direct transfer to the operating room improves care of trauma patients. *JAMA* 1978;240:1731-1733.
3. Lucette F, Kelly B, Davis K, et al. Impact of the in-house trauma surgeon on initial patient care, outcome and cost. *J Trauma* 1997; 42:490-497.
4. Hoff WS, Reilly PM, Rotondo MF, et al. The importance of the command-physician in trauma resuscitation. *J Trauma* 1997;43: 772-777.
5. Jui J, Modesitt S, Fleming D, et al. Multicenter HIV and hepatitis B seroprevalence study. *J Emerg Med* 1990;8:243-251.
6. Digiacomo JC, Hoff WS, Rotondo MF, et al. Barrier precautions in trauma resuscitation:Real-time analysis utilizing videotape review. *Am J Emerg Med* 1997;15:34-39.
7. Peitzman AB, Billiar TR, Harbrecht BG, et al. Hemorrhagic shock. *Curr Probl Surg* 1995;32:925-1002.
8. Barber AE, Shires GT. Cell damage after shock. *New Horizons* 1996;4:161-167.
9. Shoemaker WC, Peitzman AB, Bellamy R, et al. Resuscitation from severe hemorrhage. *Crit Care Med* 1996;24:S12-23.
10. Falk JL, O'Brien JF, Kerr R. Fluid resuscitation in traumatic hemorrhagic shock. *Crit Care Clin* 1992;8:323-340.
11. Cannon WB, Fraser J, Cowell EM. The preventative treatment of wound shock. *JAMA* 1918;70:618-621.
12. Poole GV, Meredith JW, Pennell T, et al. Comparison of colloids and crystalloid in resuscitation from hemorrhagic shock. *Surg Gynecol Obstet* 1982;154:577-586.
13. Skillman JJ, Restall DS, Salzman EW. Randomized trial of albumin vs. electrolyte solutions during abdominal aortic operations. *Surgery* 1975;78:289-291.
14. Lowe RJ, Moss GS, Jikek J, et al. Crystalloid versus colloid in the etiology of pulmonary failure after trauma: A randomized trial in man. *Surgery* 1977;81:676.
15. Choi PT, Yip G, Quinonez LG, et al. Crystalloids vs. colloids in fluid resuscitation: A systematic review. *Crit Care Med* 1999;27: 200-210.
16. American Society of Anesthesiologists Task Force on Blood Component Therapy. Practice guidelines for blood component therapy. *Anesthesiology* 1996;84:732.
17. Simon TL, Alverson DC, AuBuchon J, et al. Practice parameters for the use of red blood cell transfusions. *Arch Pathol Lab Med* 1998; 122:130.
18. Hebert PC, Wells G, Martin C, et al. A Canadian survey of transfusion practices in critically ill patients. Transfusion requirements in

critical care investigators and the Canadian critical care trials group. *Crit Care Med* 1998;26:482-487.
19. Hebert PC, Wells G, Blajchman MA, et al. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. Transfusion Requirements in Critical Care Investigators, Canadian Critical Care Trials Group. *N Engl J Med* 1999;340:409-417.
20. Velmahos GC, Chan L, Chan M, et al. Is there a limit to massive blood transfusion after severe trauma? *Arch Surg* 1998;133:947-952.
21. Smith LA, Barker DE, Burns RP. Autotransfusion utilization in abdominal trauma. *Am Surg* 1997;63:47-49.
22. Wade CE, Hannon JP, Bossone CA, et al. Superiority of saline/dextran over hypertonic saline during the first 30 minutes of resuscitation following hemorrhagic hypotension in conscious swine. *Resuscitation* 1990;20:49-56.
23. Kramer GC, Perron PR, Lindsey DC, et al. Small-volume resuscitation with hypertonic saline dextran. *Surgery* 1986;100:239-247.
24. Holcroft JW, Vassar MJ, Turner JE, et al. 3% and 7.5% NaCl/dextran in the resuscitation of severely head injured patients. *Ann Surg* 1987;206:278-288.
25. Bickell WH, Bruttig SP, Millnamow GA, et al. The detrimental effects of intravenous crystalloid after aortotomy in swine. *Surgery* 1991;110:529-536.
26. Stern SA, Dronen SC, Birrer P, et al. Effect of blood pressure on hemorrhage volume and survival in a near-fatal hemorrhage model incorporating a vascular injury. *Ann Emerg Med* 1993;22:155-163.
27. Bickell WH, Wall MJ, Pepe PE, et al. Immediate versus delayed resuscitation for hypotensive patients with patients with penetrating torso injury. *N Engl J Med* 1994;331:1105-1109.
28. Advanced Trauma Life Support manual. Chicago: American College of Surgeons;1997:107.
29. Savitsky JP, Doczi J, Black J, et al. A clinical safety trial of stroma-free hemoglobin. *Clin Pharmocol Ther* 1978;23:73-80.
30. Amberson WR, Jennings JJ, Rhode CM. Clinical experiences with hemoglobin-saline solutions. *J Appl Physiol* 1949;1:469-489.
31. Xu L, Sun L, Rollwagen FM, et al. Cellular responses to surgical trauma, hemorrhage, and resuscitation with diaspirin cross-linked hemoglobin solution in rats. *J Trauma* 1997;42:32-40.
32. Maxwell RA, Gibson JB, Fabian TC, et al. Resuscitation of severe chest trauma with four different hemoglobin-based oxygen-carrying solutions. *J Trauma* 2000;49:200-211.
33. Johnson JL, Moore EE, Offner PJ, et al. Resuscitation of the injured patient with polymerized stroma-free hemoglobin does not produce systemic or pulmonary hypertension. *Am J Surg* 1998;176:612-617.
34. Gould SA, Moore EE, Moore FA, et al. Clinical utility of human polymerized hemoglobin as a blood substitute after acute trauma and urgent surgery. *J Trauma* 1997;43:325-330.
35. Scalea TM, Maltz S, Yelon J, et al. Resuscitation of multiple trauma and head injury: Role of crystalloid fluids and inotropes. *Crit Care Med* 1994;20:1610-1615.
36. Porter JM, Ivatury RR. In search of the optimal end points of resuscitation in trauma patients: A review. *J Trauma* 1998;44:908-914.
37. Dunham CM, Siegel JH, Weireter L, et al. Oxygen debt and metabolic acidemia as quantitative predictors of mortality and the severity of the ischemic insult in hemorrhagic shock. *Crit Care Med* 1991;19:231-243.
38. Rutherford EJ, Morris JA, Reed GW, et al. Base deficit stratifies mortality. *J Trauma* 1992;33:417-422.
39. Davis JW, Shackford SR, Mackersie RC, et al. Base deficit as a guide to volume resuscitation. *J Trauma* 1988;28:1464-1467.
40. Vincent JL, DuFaye P, Bere J, et al. Serial lactate determinations during circulatory shock. *Crit Care Med* 1983;11:449.
41. Abramson D, Sclea TM, Hitchcock R, et al. Lactate clearence and survival following injury. *J Trauma* 1993;35:584-589.
42. Ivatury RR, Cheatham MC, Nelson LD, et al. A prospective randomized trial of end points of resuscitation after major trauma: Global oxygen transport indices versus organ specific mucosal pH. *J Am Coll Surg* 1996;183:145-154.
43. Shackford SR, Bourguignon PR, Wald SL, et al. Hypertonic saline resuscitation of patients with head injury: A prospective, randomized clinical trial. *J Trauma* 1998;44:50-58.
44. Schlag G, Krosl P, Redl H. Cardiopulmonary response of the elderly to trauma and septic schock. *Prog Clin Biol Res* 1988;264:233-242.
45. McKinley BA, Marvin RG, Cocanour CS, et al. Blunt trauma resuscitation: The old can respond. *Arch Surg* 2000;135:688-695.
46. Schwab CW, Kauder DR. Trauma in the geriatric patient. *Arch Surg* 1992;127:701.
47. Bond SJ, Eichelberger MR, Gotschall CS, et al. Nonoperative management of blunt hepatic and splenic injury in children. *Ann Surg* 1996;223:286-289.
48. Gross M, Lynch F, Canty T Sr., et al. Management of pediatric liver injuries: A 13-year experience at a pediatric trauma center. *J Pediatr Surg* 1999;34:811-816.

Physician CME Questions

To earn CME credit for this issue of Trauma Reports, *please refer to the enclosed Scantron form for directions on taking the test and submitting your answers.*

1. Physiologic mechanisms in hemorrhagic shock include:
   A. a shift from anaerobic to aerobic metabolism.
   B. increased splanchnic circulation.
   C. decreased oxygen utilization in peripheral tissue.
   D. insulin surge.

2. Which of the following is an absolute indication for blood transfusion?
   A. Persistent tachycardia
   B. Physiologic instability with ongoing blood loss
   C. Blood pressure of 140 mm/Hg
   D. Hemoglobin less than 7 g/dL

3. A patient with evidence of both hemorrhagic and neurologic shock is treated best initially with which of the following?
   A. Phenylephrine
   B. Crystalloid and dopamine
   C. Crystalloid only
   D. Dopamine only

4. The most accurate measure of adequate clinical resuscitation is:
   A. normal lactate level.

B. base deficit of -1.
C. return of normal vital signs.
D. urine output of more than 1 cc/kg/hr.

5. The primary role of the command physician in a horizontal trauma resuscitation configuration is:
A. recording events on the flow sheet.
B. initiating ECG, oximetry, and blood pressure monitoring.
C. airway control and overall management.
D. keeping control and making treatment decisions.

6. Which of the following is true for patients with hemorrhagic shock and closed head injury?
A. Craniotomy takes precedence over all other interventions.
B. Laparotomy takes precedence over craniotomy.
C. Decreasing intracerebral pressure with mannitol is the first priority.
D. CT scan of the head should be performed before laparotomy.

7. What drug is every elderly trauma patient assumed to be taking until proven otherwise?
A. Beta-blocker
B. Coumadin
C. ACE inhibitor
D. Valium

8. In a vertical resuscitation:
A. the command physician oversees the activities of other staff.
B. clinicians are assigned one specific responsibility.
C. resuscitation time generally is longer than in horizontal resuscitation.
D. chest tube placement is completed before the secondary survey is started.

9. Pediatric trauma patients differ from adults in that:
A. blood transfusion is more common in children.
B. head injuries are less common in children.
C. non-operative management of injuries is more common in children.
D. the primary and secondary surveys have different steps.

10. Which fluid is most appropriate to use during the initial phase of a trauma resuscitation?
A. Colloid
B. Crystalloid
C. Hypertonic saline
D. Poly SFH-P

CME Objectives

Upon completing this program, the participants will be able to:
a.) Quickly recognize hemorrhagic shock and the appropriate responses to it;
b.) Be educated about resuscitation fluids and when fluids should be administered or withheld;
c.) Understand the most efficient way of conducting a trauma resuscitation;
d.) Understand factors that affect resuscitations in patients who are elderly or pediatric, or who have closed head or spinal cord injuries; and
e.) Recognize the goals and endpoints of resuscitation.

In Future Issues: **Pelvic Fractures**