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Trauma is the leading cause of death in children older than age 1. Although injury prevention and education are by far the most cost-effective methods for reducing the enormous burden of pediatric injury, the appropriate treatment of severely injured children—particularly the timely recognition of shock and rapid institution of intravenous fluid resuscitation—also will reduce pediatric trauma mortality.

Among trauma deaths, shock is second only to respiratory failure as the most common cause of death in children. Recognition of shock, however, is difficult because shock is not a single process but rather a complex series of inter-related events. At its most fundamental level, shock is the condition in which a collapsed circulatory system fails to meet the energy demands at the cellular level. Successful treatment of shock requires the restoration of substrate delivery—chiefly oxygen—to the tissues. This is accomplished by increasing oxygen tension (through the use of supplemental oxygen), re-expanding the vascular space (by intravenous infusion of crystalloid), and, when necessary, increasing the oxygen-carrying capacity of the vascular system (by transfusing blood).

The body water composition of children varies with age. At birth, the body is 75% water, at 1 year it is 65% water, and the water content of an adult is 55-60%.[1] Pediatric blood volume, at 80-90 mL/kg, also is higher than the usual adult volume of 70 mL/kg.[2] Thus, appropriate and timely fluid resuscitation in the child is even more important than in the adult; it is the key to restoring homeostasis after injury.

— The Editor

Fluid Resuscitation in the Pediatric Trauma Patient

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Recognizing Shock in the Pediatric Trauma Patient

When an injured child arrives in the trauma room, it is critical to recognize the early, subtle signs of shock and institute appropriate therapy. The trauma history, including the injury mechanism, can provide important information. High-energy transfer mechanisms (e.g., motor vehicle crashes, falls from heights, and firearm injuries) obviously increase the risk of shock. A large amount of blood at the scene of the injury (as reported by an experienced observer) also may be a positive predictor of shock. Finally, the amount of IV fluids administered en route to the trauma center should be included in the trauma history and compared to the patient's known or estimated weight to determine the fluid volume per kilogram that has been administered.

The physical examination of the pediatric trauma patient begins with the same stepwise evaluation used for adults. Advanced Trauma Life Support (ATLS) is the most widely taught strategy, and consists of a rapid assessment for life-threatening injuries (airway, breathing, circulation) followed by a head-to-toe assessment, or secondary survey. Although a complete description of ATLS is beyond the scope of this monograph, one of its key concepts is that physical examination and resuscitative measures are performed simultaneously. For example, when the airway is examined, the patient is placed on 100% oxygen; evaluation of breath sounds may indicate the need for immediate chest tube placement; and evaluation of circulation for signs of shock occurs simultaneously with initiation of fluid resuscitation.

Shock often is classified by etiology: hypovolemic, cardiogenic, obstructive (such as cardiac tamponade or tension pneumothorax), or distributive (such as neurogenic or septic shock).[3] Although the shock in pediatric trauma most frequently is due to hypovolemia, other types of shock may occur as well. Neurogenic shock can be quite severe in a child with a cervical spine injury. A child with an abdominal injury from a lap belt may develop hypovolemic shock from a bleeding liver injury, for example; neurogenic shock may result from a spinal cord injury, and, if treatment is delayed, septic shock may result from an intestinal perforation.

For teaching purposes, hemorrhagic shock is divided into four categories based on signs, symptoms, and estimated degree of blood loss. Mild tachycardia is the only sign of a Class I hemorrhage (less than 15% blood loss). For Class II hemorrhage (15-30% blood loss), tachycardia may be accompanied by tachypnea, diminished pulse pressure, prolonged capillary refill, and anxiety. Class III hemorrhage (30-40% loss) causes profound hemodynamic changes, including tachycardia, tachypnea, hypotension, oliguria, and mental status changes. Finally, patients with Class IV hemorrhage (> 40% blood loss) usually are hypotensive, anuric, and comatose.[2]

As noted above, recognition of shock, particularly early or mild shock, is the most demanding aspect of the pediatric trauma evaluation. Tachycardia is the most sensitive indicator of pediatric shock, but is non-specific because pain and anxiety also increase heart rate. Nevertheless, shock cannot be ruled out in a tachycardic child until a complete physical examination (and perhaps re-examination) fails to disclose any other signs or symptoms of shock. Blood pressure can be high, low, or normal in a child who is in shock. Although hypotension has a high specificity for shock, it has a low sensitivity, and generally occurs only after a child has lost 30% or more of circulating blood volume.[4] In fact, hypotension in the pediatric trauma patient is a sign that complete cardiovascular collapse is imminent.[1]

The "fatal five" signs for pediatric shock are tachycardia, altered mental status (depressed level of consciousness or irritability), respiratory compromise, decreased or absent peripheral pulses, and delayed capillary refill (> 2 seconds). While the utility of capillary refill has been questioned in adults,[5] it is considered a reliable sign in children.[6-8] The child in shock often is pale and mottled, and the extremities may be cool. The importance of a careful (and repeat) physical examination cannot be overemphasized. It is the most sensitive tool for detecting early shock.

Despite the efforts of multiple instructional courses, including Pediatric Advance Life Support (PALS), ATLS, and Emergency Nurse Pediatric Course (ENPC), shock recognition remains difficult for those who do not primarily care for children. The classic pitfall of the inexperienced house officer is to perform an airway-breathing-abdomen primary survey, instead of airway-breathing-circulation—thus failing to examine peripheral pulses, capillary refill, and other signs of poor perfusion. A recent retrospective study compared general surgery residents with extensive training at Level 1 adult trauma centers to pediatric surgery fellows in their ability to recognize shock in pediatric trauma patients. The study showed that pediatric surgery residents were eight times more likely than general surgery residents to recognize shock correctly in pediatric trauma victims.[9]

Initial Resuscitation

IV Access. Perhaps no aspect of pediatric trauma care is more frustrating than vascular access in a child who is in shock. Infants and toddlers, who not only have small veins but also more abundant subcutaneous fat, are the most challenging. The standard for pediatric trauma is two peripheral IV lines, using the largest catheters the veins will accommodate. If access is not obtained after three attempts, or 90 seconds in a critically ill child, an intraosseous infusion should be considered.[10] Almost any resuscitative fluid can be

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administered through an intraosseous line, including crystalloid fluids, albumin, whole blood, and packed red blood cells (PRBCs). Sodium bicarbonate, lidocaine, catecholamines, and calcium chloride also may be infused.[1] Although intraosseous infusions generally are best accomplished in children younger than age 6,[11] they have been used successfully in children as old as age 10.[12] The intraosseous line is an excellent emergency access method that requires minimal equipment and experience. It is easily performed in the trauma room. Nevertheless, the intraosseous line should not be left in place for more than a few hours, because the risk of complications (compartment syndrome, skin necrosis, and osteomyelitis) increases with time. The overall complication rate associated with intraosseous lines is less than 1%.[8]

Central venous catheterization (particularly using the femoral approach) has been promoted by some authors for emergency vascular access for pediatric trauma.[13] However, although there is no direct comparison study, this route clearly is more time-consuming. In one study, the average procedure time for subclavian catheterization was 8.3 minutes.[14] A different study reported that untrained medical students could place an intraosseous line (in an animal bone model) in 33-54 seconds.[15] Furthermore, central venous catheters are associated with potentially life-threatening complications (pneumothorax, hemothorax, great vessel injury), whereas intraosseous infusions generally are not. Central venous access should be performed under controlled conditions after initial stabilization has been completed. It should be performed only as a last resort in the trauma room.

Administration of Resuscitative Fluids. Warmed crystalloid fluids are universally recommended for initial pediatric trauma resuscitation.[1,3,4,16,17] Compared to colloid solutions, crystalloid fluids are less expensive and more widely available,[11] but offer the same survival benefit in patients with trauma or burns.[18] Furthermore, it appears that albumin or artificial plasma expanders are no more effective for restoring perfusion than crystalloid solutions when adequate sodium is provided.[17] Others argue that colloid solutions remain in the intravascular compartment longer and are, therefore, much more efficient volume expanders.[8] Nevertheless, the sensitivity reactions associated with colloid solutions limit their use.

Either normal saline or lactated Ringer's solution (LRS) can be used for crystalloid infusion.[8] However, some authors express a preference for LRS because lactate is metabolized to bicarbonate by the liver and therefore buffers acidosis. Furthermore, hyperchloremic metabolic acidosis can be seen with rapid administration of saline.[11] For suspected shock, an initial fluid bolus of 20 mL/kg (warmed) is rapidly administered over 5-10 minutes while vital signs are monitored for an appropriate response. For a child heavier than 20 kg, a rapid infuser device should be considered.[10]

If there is no response, the fluid bolus should be repeated. Children who respond to a fluid bolus will have a slowing of heart rate and improved signs of perfusion (such as return of normal skin color, increased warmth of extremities, and clearing of sensorium). If there is no response, a second fluid bolus may be given. If a third bolus is initiated, strong consideration should be given to directly involving a surgeon (if one is not present already) and infusing 10 mL/kg of type-specific or O-negative warmed PRBCs.

Blood and blood products can be transfused in a pediatric patient in intravenous catheters that are 22 gauge or larger, but also can be given through an intraosseous needle. Initial transfusion amounts are generally 10-12 mL/kg. The most common complication of large-volume transfusion is hypothermia, which leads to acidosis, vasoconstriction, and a leftward shift of the hemoglobin-oxygen dissociation curve (increasing the affinity of hemoglobin to oxygen, decreasing the delivery of oxygen to the tissues)—essentially negating the beneficial effect of increasing the red cell mass. Therefore, preventing hypothermia is crucial when transfusing critically injured children. Hypocalcemia and hyperkalemia also are seen occasionally following a massive transfusion.

Novel resuscitative fluids currently under investigation include Isosal, a low-sodium (13.45%), 2400 mOsm/L hypertonic fluid; and 7.5% hypertonic saline solution. Although both of these solutions have been shown to effectively resuscitate a pediatric shock animal model using intraosseous infusion,[19] their clinical usefulness is not known and they currently are not recommended.

Hypothermia. Hypothermia is part of the "vicious circle" of pediatric trauma: A hypothermic child will develop shock and a child in shock will develop hypothermia. Hypothermia increases peripheral vasoconstriction, worsens acidosis, and decreases oxygen delivery to the tissues.[1] Successful treatment of hypothermia depends not only on the appropriate application of warming measures but also on the restoration of normal hemodynamics by administration of resuscitative fluids. Although there are studies documenting that hypothermia improves outcome in pediatric head injury, it must be pointed out that these patients undergo a carefully monitored, physician-induced hypothermia following their injury. In general, these patients already are resuscitated before the hypothermia begins, and frequently they require large doses of vasopressors while hypothermic.

There are three traditional approaches to treating hypothermia: passive peripheral warming, active peripheral warming, and core warming. Although the scientific support for each of these techniques is slim, they all are used in pediatric trauma. Much of the literature on hypothermia is based on adult trauma patients or postoperative (non-trauma) patients.

Passive peripheral warming involves the application of insulating materials (usually blankets) to prevent further heat loss. This technique begins at the point of injury, where emergency medical services personnel place insulated blankets on the injured child. Passive warming works best on older children with core temperatures greater than 32.2°C/89.9°F.[20] Although passive warming is one of the most common techniques used, its efficacy is untested and dubious because children in shock do not generate heat.

Active peripheral warming uses an externally warmed medium (generally hot air or a hot surface) to transfer heat to the patient. This usually is begun when the patient arrives in the hospital and is maintained until the patient reaches normothermia. Although there is evidence that these devices are effective for postoperative patients, their value in the trauma setting, where patients frequently are moved from place to place and are often uncovered for repeat examinations, is unknown.[20] Nevertheless, every attempt should be made to keep the trauma room environment as warm as possible, and the use of active warming blankets is encouraged.

Core warming requires the administration of warmed fluids directly into the vascular space. In most instances, this involves the use of multilumen IV tubing, with a outer jacket of warmed water circulating around the IV fluids up to the point where the fluids enter the patient's vascular system. This technique appears to be most useful for pediatric trauma patients, but its effectiveness is proportional to the rate of intravenous infusion. It probably is most effective when combined with active peripheral warming measures.[20]

Although continuous venovenous rewarming has been described for hypothermic adult trauma patients, there is little published clinical data in children. The small blood vessel size and blood volume of pediatric patients makes the use of rewarming circuits particularly challenging.[21] Nevertheless, an experimental model, using 5-week-old goats, demonstrated the efficacy of this modality in a juvenile model.[22] Because of the rarity of these cases, it is unlikely that a clinical trial of extracorporeal rewarming circuits ever will be conducted.

Special Situations

Head Injury. Among pediatric trauma patients, head injury is a leading cause of death. Severe head injury may be associated with cerebral edema leading to increased intracranial pressure (ICP) and decreased cerebral perfusion pressure (CPP). The decreased perfusion of the brain leads to decreased cerebral oxygen delivery and subsequent ischemic injury. The major goal after head trauma is to prevent and treat cerebral ischemia as soon as possible.[23] The ideal therapy restores systemic and cerebral perfusion without worsening cerebral edema and increasing ICP. It has been demonstrated that, in pediatric trauma patients with a Glasgow coma score of less than 8, the most critical factor for survival is the adequacy of resuscitation.[24]

In the past, patients with severe head injury were treated with high dose glucocorticosteroids, fluid restriction, and hyperventilation to prevent cerebral edema. It now is recognized that glucocorticosteroids have no effect on the outcome and actually may exacerbate secondary brain injury.[25,26] In addition, fluid restriction may result in hypovolemia, placing the patient at risk for hypotension and decreased CPP. Moderate hyperventilation, used in the appropriate patient with ICP and systemic monitoring, can help lower elevated ICP. Nevertheless, hyperventilation therapy remains controversial, and a recent review recommends that it should not be used as first-line treatment for intracranial hypertension.[27] Currently, the recommendations for fluid resuscitation of a patient with severe head injury are 20 mL/kg of an isotonic crystalloid, such as 0.9% NaCl, as soon as vascular access is obtained. Hypotonic fluid should not be used as the initial resuscitation fluid. Isotonic crystalloid, colloid, or PRBCs can be used for subsequent fluid administration.[28]

Hypertonic solutions have been shown to restore hemodynamic parameters in hypotensive and head injured trauma patients, as well as decrease ICP following a decrease in the volume of brain tissue by extraction of water.[29] By contrast, the infusion of large volumes of hypotonic fluids can increase ICP, resulting in a poor neurologic outcome.

It has been suggested that hypertonic saline should be used as the initial resuscitation fluid in the head injury patient. The basis for using hypertonic saline solution relates to the movement of water across the intact blood-brain barrier. The major force for this movement is the osmotic gradient, which is calculated as osmolality = $2(Na^+ + K^+)$ + (BUN/2.8) + (Glucose/18). Small changes in serum sodium lead to large changes in osmotic pressure gradient and water movement.[23]

Studies in both animals and humans have shown that hypertonic saline improves systolic blood pressure, cardiac output, cerebral blood flow, and cerebral oxygen delivery, while decreasing intracranial pressure.[29-40] The effect of decreasing ICP diminishes after 72 hours of infusion.[41] In one study, children who were treated initially with hypertonic saline as a resuscitation fluid had fewer complications and interventions to maintain a target ICP. The increase in serum sodium levels and transient mixed acidosis resulting from infusion of hypertonic saline did not adversely effect resuscitation.[42] As mentioned previously, the current recommendation for fluid resuscitation of the patient with head injury is an isotonic crystalloid solution. However, extensive animal data and a few human studies have shown that hypertonic saline may be ideal for the treatment of intracranial hypertension.[32-44] More studies will be needed in this area to determine if hypertonic saline will lead to a better neurologic outcome in pediatric head trauma.

More recently, it has been suggested that in cases of refractory intracranial hypertension after trauma in an adult patient in whom conventional therapy (mannitol, hyperventilation, furosemide) has been optimized, 10% or 23.4% hypertonic saline may be used instead of 3% hypertonic saline.[45,46] In these situations, the intravenous bolus administration of the hypertonic saline reduced ICP and augmented CPP, with the effect lasting for several hours. There also were no acute complications in the population after treatment. Isosal, with its lower sodium content, was found to be as effective as hypertonic saline in resuscitation for severe hemorrhagic shock in a pediatric animal model, and produced significantly less hypernatremia.[19] More studies will be needed in this area to determine its potential application to traumatic head injuries in children.

Burns. More than 2 million burn injuries occur annually, resulting in more than 150,000 hospital admissions. The victims most commonly are the elderly or children, and their death rate is five times greater than that of other groups.[47,48] House fires are the leading cause of death in the home in children younger than age 14, and scald injury is the most common form of burn injury in children younger than age 5.[47-49] The burn wound is characterized by loss of plasma into the injured tissue. Early fluid resuscitation after severe thermal injury has been demonstrated to reduce multi-organ failure and mortality.[50-52]

Resuscitation of the burned child remains challenging for several reasons. Children require more precise therapy than adults with similar burns. Children may need to be admitted and administered formal intravenous resuscitation for relatively small burns and require more fluid than adults with similar injuries.[53-55] Also, children have a limited physiologic reserve. In the very young child, the increased ratio of body surface area to body mass increases the challenge of fluid resuscitation and increases the risk of hypothermia.

The goal of fluid resuscitation in the first 24 hours is to restore fluid volume to normal and correct any electrolyte abnormalities while minimizing edema formation that results from increased systemic capillary permeability.[56] The choice of resuscitation fluid usually is an isotonic fluid such as LRS. The volume to be infused is predicted by the burn size and the body weight. Restoring plasma volume after a severe thermal injury is a major concern, as it has been demonstrated that patients with a delayed initiation of fluid resuscitation following injury have a worse prognosis for survival.[51,57,58] Increased systemic capillary permeability accounts for the amount of fluid lost through the burn wound in the first 24 hours.[56] Mortality rates increase with the amount of time between injury and the initiation of fluid resuscitation. The mortality rate for patients who received fluid resuscitation within two hours of injury is 14%; mortality increases to 61% when fluid resuscitation is not initiated until 2-4 hours or longer after injury.[56] Mortality increases to 91% when resuscitation is delayed by 4-12 hours in burns involving 50% or more of the body surface area (BSA).[56] It also has been demonstrated that early fluid resuscitation after thermal injury results in a lower incidence of sepsis and renal failure, fewer deaths from cardiac arrest, and lower overall mortality.[56]

Transportation of the thermally injured patient to an emergency facility should never be delayed if there is an inability to obtain intravenous access. It is acceptable to transport a patient without obtaining pre-hospital IV access if the admitting hospital is fewer than 60 minutes from the scene. When pre-hospital IV access is established, LRS should be infused at 250 mL/hr in patients ages 5 years and older.[47]

A patient with major burns or inhalation injury and other associated injury will need an intravenous line established for resuscitation. Peripheral lines in the upper extremity are preferred. A minimum of two large-caliber IV catheters should be placed through non-burned tissue. If non-burned tissue is not available, then the catheters can be placed through burned tissue. The Parkland formula and the modified Brook formula are the two most commonly used formulas for estimating fluid needs in the thermally injured patient. The Parkland formula is 4 mL/kg/% of BSA burned, and the modified Brooke formula is 2 mL/kg/% of BSA burned. These generally are combined and presented as the consensus formula of 2-4 mL/kg/% of BSA burned. All of the formulas require one-half of the total amount to be given over the first eight hours from the time of injury and the second half to be given over the following 16 hours. The Shriner's Burn formula recommends that initial resuscitation in pediatric patients should be with 5000 mL/m^2% of BSA burned/day + 2000 mL/m^2/BSA total/day LRS. This formula takes into account the higher evaporative loss in the pediatric patient and also requires that one-half of the total volume of fluid is given in the first eight hours after injury and one-half of the total amount is given over the following 16 hours.[47]

Resuscitation formulas are designed to serve as a guide for fluid resuscitation, and it is the response of the patient to fluid administration that is most important. Additional fluid above that calculated by a resuscitation formula commonly is needed with inhalation injury, electrical burns, associated trauma, and delayed resuscitation. Inadequate resuscitation can cause diminished perfusion of the renal and mesenteric vascular beds while excessive fluid administration can produce pulmonary or cerebral edema.[47] The best monitor of the adequacy of fluid replacement in the thermally injured patient is urine output. In children, an acceptable degree of hydration is indicated by a urine output of 1 mL/kg/hr. Diuretics are not indicated during the acute resuscitation period unless there is a history of high voltage electrical burns or crush injuries. In these situations, there may be myoglobin and/or hemoglobin in the urine that increases the risk of renal tubular obstruction. These patients should have sodium bicarbonate added to their IV fluids to alkalinize the urine, and urine output should be maintained at 1-2 mL/kg/hr while myoglobin or hemoglobin remain in the urine. An osmotic diuretic such as mannitol may be needed to help clear the urine of the pigments.

Some research investigations into the Parkland formula for burn resuscitation have suggested that half of the calculated fluid volume should be given over four hours rather than the recommended eight hours.[59] This change in the fluid delivery is designed to reduce hypovolemia, preserve vital organ function, and reduce morbidity. It has been demonstrated that patients receiving rapid infusion of isotonic fluid have a decreased need for mechanical ventilation, increased normalization of vital signs, increased urine output, and normalization of urine specific gravity. These patients did receive more fluid and sodium, but there was no significant increase in tissue edema. Multicenter, prospective, controlled studies will need to be performed before this method of fluid resuscitation can be universally recommended.

Blunt Abdominal Trauma. Pediatric abdominal trauma, when compared to adult abdominal trauma, differs in injuries incurred, management, and outcome. These differences are explained by physiologic and anatomic features present in the pediatric patient. Solid abdominal organs are relatively larger in children, which increases the risk of direct injury from blunt trauma. Furthermore, young children have poorly developed abdominal muscles, the internal organs have less fatty insulation, and the suspension of the organs tends to be more elastic. Abdominal distention caused by swallowed air is common in children, and younger children may not be able to communicate the presence of pain. These factors contribute to an exam that is less reliable. The bladder is an intra-abdominal organ in young children, which may predispose it to injury. Also, the chest wall has increased flexibility, which allows for major incursion following trauma, compressing internal organs without showing any external signs of injury. A smaller body size allows a traumatic force to be distributed over a smaller mass. This can lead to a greater number of injuries during a traumatic event.[60]

Initial resuscitation begins with insertion of two large-bore intravenous catheters. If the child is hemodynamically unstable, aggressive fluid resuscitation is begun with 20 mL/kg of warmed crystalloid such as normal saline. The fluid is given by rapid bolus and repeated one or two times if needed. Blood should be sent for a type and cross-match. If hemodynamic instability persists, 10-20 mL/kg of warmed blood is given. If instability persists after blood transfusion, laparotomy is indicated.[61]

There has been some controversy over the pre-hospital administration of large amounts of IV fluids because some studies demonstrated that this was associated with increased mortality.[62-64] Several mechanisms have been proposed to contribute to these findings, such as hydraulic acceleration of ongoing hemorrhage secondary to elevated systemic blood pressure, disruption of thrombus at the bleeding site, and dilution of clotting factors.[65] A study comparing adults with penetrating trauma who received pre-hospital intravenous fluid and those who did not demonstrated a survival advantage for the non-intravenous fluid group.[66] A subsequent subset analysis revealed that the survival was improved only in patients with penetrating cardiac injuries.[67] There have been no prospective studies addressing pre-hospital intravenous fluid administration in adults with blunt trauma or children with penetrating or blunt abdominal trauma. Therefore, pre-hospital fluid administration remains an important component of pediatric trauma care. However, findings suggest that it may be detrimental to the patient for an excessive amount of time to be spent at the scene attempting to establish an IV, when the optimum care of the patient is rapidly available at a nearby trauma center.[61,66]

Vascular Injury. Traumatic vascular injury is not as common as iatrogenic vascular injury in children. Injuries often occur in larger, older children. The most common injuries are vascular disruption secondary to proximal skeletal fracture and vessel damage from penetrating injury. Vascular injuries in the older child can be addressed as those in an adult would be. The absence of pulses in a cool or mottled extremity requires surgical exploration within six hours of injury.

Occasionally, vascular injuries can present with dramatic wounds and associated hemorrhage. Examples include lawnmower injuries, impalement injuries, and falls through plate-glass windows. It is important to remember to treat the patient first and the extremity second. The primary survey (airway, breathing, circulation), including initiation of fluid resuscitation, is the top priority. Bleeding wounds should be controlled with direct pressure, IV lines should be placed, and blood should be sent for type and cross-match.

Early diagnosis of vascular injuries requires a high index of suspicion. All injuries with common signs of vascular damage (such as significant hematoma formation, palpable thrill, absent or diminished pulses, active hemorrhage, or distal ischemia) should undergo immediate operative exploration and repair. In patients with soft signs (such as a small, stable hematoma, injury to an anatomically related nerve, unexplained hypotension, history of hemorrhage no longer present, or proximity of injury to a major vessel), percutaneous angiography can be undertaken.[68] Even if active bleeding is not present, large-bore IV access should be established and blood should be cross-matched, in case urgent repair is needed.

Bleeding from a vascular injury usually can be controlled by direct pressure. A tourniquet will compromise salvage of the distal extremity and should not be used. It is important to restore perfusion to the affected limb by correcting hypovolemia with intravenous fluid resuscitation and reducing gross limb deformity.

Children with vascular injuries should be transferred to a regional pediatric trauma facility. Intravenous fluids and resuscitation can be initiated at the scene of the injury and initial stabilization can be performed at an outlying facility, if needed. Monitoring of telemetry data while the patient is being transported to a trauma facility will give important information about the cardiorespiratory status.[69]

Conclusion

Recognition of shock in the pediatric trauma victim is a challenging task for the clinician. Early recognition of shock must be followed by initiation of appropriate resuscitation, including not only administration of intravenous fluids, but also treatment and prevention of hypothermia. A cold pediatric trauma patient will respond poorly to resuscitation, and hypothermia essentially negates the benefits of volume resuscitation. The trauma room should be uncomfortably warm for the trauma team, but cozy for the patient.

Because of the extremely responsive cardiovascular system of the child, "classic" signs of shock such as hypotension and anuria do not appear until circulatory collapse is imminent. Furthermore, because shock is the end result of a complex series of events, there is no single "test" to reliably detect its onset. The best study to identify the onset of shock is a complete primary and secondary survey, followed by frequent, repeat examinations.

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CME Objectives

Upon completing this program, the participants will be able to:
— Quickly recognize or increase index of suspicion for shock in the pediatric trauma patient;
— Correctly perform necessary diagnostic tests and take a meaningful patient history that will reveal the most important details about shock and/or the need for fluid resuscitation;
— Utilize state-of-the-art fluid resuscitation techniques (including the implications of pharmaceutical therapy discussed) to patients in shock and apply the appropriate type of resuscitation in the special situations described.

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. An 8-year-old boy falls while riding his bicycle and sustains a handlebar injury to the right upper quadrant. He has a tense and tender abdomen and is in pain. His heart rate is 120 beats/min, blood pressure is 120/80, and capillary refill is normal. What level hemorrhage would you suspect?
   A. Class I
   B. Class II
   C. Class III
   D. Class IV

2. An advantage of lactated Ringer's solution (LRS) over normal saline for IV resuscitation is:
   A. the potassium in LRS replaces potassium lost due to traumatic injury.
   B. LRS is less likely to cause pulmonary edema.
   C. the lactate in LRS is converted to bicarbonate by the liver.
   D. LRS is less expensive and easier to obtain than normal saline.

For Questions 3-5: *A 6-year-old child was a restrained passenger (lap belt only) in a motor vehicle crash with fatalities. Extrication time was 20-30 minutes. On arrival, the patient is pale, anxious, has cool extremities and a distended abdomen. His heart rate is 150, blood pressure is 100/60, and you estimate his weight at 25 kg.*

3. Two minutes after arrival, the trauma team is unable to establish IV access despite four attempts. The next step should be to:
   A. place an intraosseous line in the sternum.
   B. place an intraosseous line in the tibia.
   C. place a central line in the subclavian vein.
   D. place a central line in the femoral vein.

4. Approximately how much blood has this child lost?
   A. Less than 15%
   B. 15%-30%
   C. 30%-40%
   D. Greater than 40%

5. How much IV fluid should he receive before he receives blood?
   A. 250 mL
   B. 500 mL
   C. 750 mL
   D. 1000 mL

6. Which of the following is generally considered ineffective (and possibly injurious) to children with head injuries?
   A. Glucocorticosteroids
   B. Lactated Ringer's solution
   C. Hypertonic saline
   D. Normal saline

7. Burn resuscitation in children is more demanding than in adults for all of the following reasons *except:*
   A. Young children have an increased mass to body surface area ratio.
   B. Young children may require fluid resuscitation for relatively small burns.
   C. Young children are more prone to hypothermia.
   D. Young children have a limited physiologic reserve.

8. A 10-year-old male presents with an isolated injury consisting of a laceration of the right forearm, with active hemorrhage and a diminished radial pulse. The first step in treating this patient should be to:
   A. apply a tourniquet to the injured extremity to stop bleeding.
   B. apply direct pressure to the injured extremity to stop bleeding.
   C. obtain vascular access.
   D. examine the patient's airway.

9. A child with blunt trauma to the abdomen, tachycardia, and poor perfusion should receive all of the following *except:*
   A. 100% oxygen.
   B. IV access.
   C. 20 cc/kg 0.9 NS fluid bolus.
   D. fluid restriction.

10. Which of the following statements regarding hypertonic saline is *incorrect*?
    A. It improves systolic blood pressure.
    B. It increases intercranial pressure.
    C. It improves cardiac output.
    D. It improves cerebral oxygen delivery.

In Future Issues: Penetrating Extremity Trauma

Trauma Reports

September/October 2001 CME Evaluation

Dear Subscriber,
In order to better meet your CME needs, *Trauma Reports* is conducting this survey. Your feedback is an integral part of making our CME program more valuable to you. We welcome your opinion, and we thank you for taking the time to respond to this important survey.

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   _____Always
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   _____Yes _____No

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   _____Excellent
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