Symposium on Pediatric Trauma

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Initial assessment and management of pediatric trauma patients

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ABSTRACT

Injury is the leading cause of death and disability in children. Each year, almost one in six children in the United States require emergency department (ED) care for the treatment of injuries, and more than 10,000 children die from injuries. Severely injured children need to be transported to a facility that is staffed 24/7 by personnel experienced in the management of children, and that has all the appropriate equipment to diagnose and manage injuries in children. Anatomical, physiological, and emotional differences between adults and children mean that children are not just scaled-down adults. Facilities receiving injured children need to be child and family friendly, in order to minimize the psychological impact of injury on the child and their family/carers. Early recognition and treatment of life-threatening airway obstruction, inadequate breathing, and intra-abdominal and intra-cranial hemorrhage significantly increases survival rate after major trauma. The initial assessment and management of the injured child follows the same ATLS® sequence as adults: primary survey and resuscitation, followed by secondary survey. A well-organized trauma team has a leader who designates roles to team members and facilitates clear, unambiguous communication between team members. The team leader stands where he/she can observe the entire team and monitor the "bigger picture." Working together as a cohesive team, the members perform the primary survey in just a few minutes. Life-threatening conditions are dealt with as soon as they are identified. Necessary imaging studies are obtained early. Constant reassessment ensures that any deterioration in the child's condition is picked up immediately. The secondary survey identifies other injuries, such as intra-abdominal injuries and long-bone fractures, which can result in significant hemorrhage. The relief of pain is an important part of the treatment of an injured child.

Key Words: Initial assessment, injury, pain, pediatric, primary survey, trauma

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INTRODUCTION

Anatomical, physiological, and psychological differences between children and adults have important implications for the initial assessment and management of pediatric trauma victims.

Children have less fat, more elastic connective tissue, and a pliable skeleton protecting tightly packed abdominal and thoracic structures. The force of an impact is transmitted widely through a child's body, resulting in multisystem injuries in almost 50% of children with serious trauma.[1] Their larger body surface area to body mass ratio predisposes them to larger heat and insensible fluid loss than adults, resulting in higher fluid and caloric requirements.

Children have a different physiological response to major trauma compared to adults, in that they maintain a near-normal blood pressure even in the face of 25% to 30% of blood volume loss. In these situations, subtle changes in the heart rate and extremity perfusion may signal impending cardiorespiratory failure, and should not be overlooked.[2]

Children may not cope well emotionally in the aftermath of an accident. They need to be managed in a calm, child-friendly environment. The presence of a parent or guardian in the resuscitation room may help the trauma team by minimizing the injured child's fear and anxieties. There is evidence that 25% of children suffer from post-traumatic stress disorder after a motor vehicle collision.[3]

A rapid and well-organized team assessment of an injured child, following ATLS® guidelines, is essential. The term *golden hour*, while not literally defined, refers to an early and critical period in the care of trauma victims, during which the appropriate management may significantly increase patients' survival rate. The goals of initial stabilization include providing adequate oxygen delivery and ventilation, fluid resuscitation, and prevention of secondary damage to target organs. The decision of whether the injured child will be transferred to a trauma center or to the closest available facility largely depends on geographic location and local policies. There is some controversy surrounding the optimal type of facility for the management of pediatric trauma. Osler *et al*. reviewed 53,113 children included in the National Pediatric Trauma Registry.[4] They found a higher mortality in children who were treated in adult trauma centers (ATCs) than in pediatric trauma centers (PTCs). However, children admitted to ATCs were more severely injured. When this was accounted for, they did not find a difference in mortality. Potoka *et al*. reviewed 13,351 children included in the Pennsylvania Trauma Outcome Study.[5] They found that overall survival was significantly better at PTCs and ATCs with added qualifications to treat children (ATC-AQs) compared with ATCs. In this study, patients treated at PTCs and ATCs had similar injury severity. Oyetunji *et al*. analyzed 53,702 children from the National Trauma Data Bank.[6] They found that mortality was significantly lower in ATC-AQs versus ATCs. On a multivariate analysis, the adjusted odds ratio of mortality for all patients was 20% lower at ATC-AQs than at ATCs.

PRIMARY SURVEY

The primary survey is presented in a sequential fashion, but in reality the trauma team, directed by a team leader, performs the components of the primary survey simultaneously, so that the entire process takes only a few minutes. The goal of the primary survey is to find and relieve immediate life-threatening conditions. The primary survey starts at the injury scene and aims to ensure a patent airway, adequate breathing, circulatory support, and to assess major neurologic disability. The primary survey includes frequent reassessment to confirm or exclude injuries that require immediate surgical intervention.

The 2010 American Heart Association resuscitation guidelines changed from an A-B-C sequence to a C-A-B sequence for adults and children.[7] In the trauma scenario, this translates to checking for a pulse and starting external cardiac compressions if one is not felt, before turning attention to the airway. Major exsanguinating hemorrhage, including hemorrhage resulting from pelvic fractures, needs to be controlled as a matter of urgency, at the same time as the assessment of the airway. A recent review suggested that almost 22% of cardiac arrests in children are associated with trauma.[8] In a 10-year review of children requiring pre-hospital CPR after traumatic injury, 8.75% survived to hospital discharge.[9] In a different 11-year review, 16% survived. Half of these survivors were neurologically normal. None of the children who required ongoing CPR on arrival at the trauma center survived.[10]

AIRWAY

The assessment of the airway simply involves determining the ability of air to pass unobstructed into the lungs. The airway can be obstructed anywhere between the lips and the carina, by direct trauma, edema, secretions, blood, stomach contents, or foreign bodies. If the level of consciousness (LOC) is depressed, the child may not be able to maintain a patent airway and/or be able to protect the lungs from aspiration of stomach contents, because of loss of the gag reflex.

The classic sign of upper airway partial obstruction is inspiratory stridor. Respiratory effort with no air flow indicates complete airway obstruction.

BREATHING

Evaluate breathing to determine the child's ability to ventilate and oxygenate.

Anticipate respiratory failure if any of the following signs is present:

- an increased respiratory rate, particularly with signs of distress (e.g. increased respiratory effort including nasal flaring, retractions, seesaw breathing, or grunting);
- an inadequate respiratory rate, effort, or chest excursion (e.g. diminished breath sounds or gasping), especially if mental status is depressed;
- cyanosis with abnormal breathing despite supplementary oxygen.[7]

Critical findings include the absence of spontaneous ventilation, absent or asymmetric breath sounds suggesting pneumothorax or endotracheal tube (ETT) malposition, hyper-resonance or dullness to chest percussion suggesting tension pneumothorax or hemothorax, respectively, and gross chest wall instability or defects that compromise ventilation (e.g. flail chest or sucking chest wound).

Care should be taken in the interpretation of pulse oximetry readings. A child may be in impending respiratory failure despite maintaining normal O_2 saturations (SpO_2), especially when supplementary O_2 is being administered. Pulse oximetry only indicates SpO_2 and not oxygen delivery. If the hemoglobin is very low, the SpO_2 may be 100%, but O_2 content in the blood and O_2 delivery may be low. If carboxyhemoglobin (from carbon monoxide poisoning) is present, the pulse oximeter will reflect a falsely high SpO_2.

CIRCULATION

Vascular access, fluid, and blood component therapy for pediatric trauma victims are discussed in a separate article in this issue of the journal.

CERVICAL SPINE INJURIES

While spinal cord injuries are rare in children (<2% of injured children), a missed injury may have devastating consequences for the child, not to mention medico-legal ramifications for the trauma team. All significantly injured children must be assumed to have a cervical spine injury until proven otherwise by objective clinical examination. Approximately 30-40% of children with traumatic myelopathy have spinal cord injury without radiological abnormality (SCIWORA).[11]

The National Emergency X-Radiography Utilization Study found that applying the following five clinical criteria for *not* obtaining cervical spine imaging in pediatric blunt trauma had a sensitivity of 99%: no midline cervical tenderness, no focal neurologic deficit, normal alertness, no intoxication, and no painful, distracting injury.[12] A prospective study done in 3065 patients younger than 18 years showed that when using these criteria, there was 100% sensitivity and a 100% negative predictive value.[13] All other children must have their spine immobilized with an appropriately fitted cervical collar until cleared clinically or by MRI at 72 h post-injury. Initial X-ray evaluation should routinely consist of three views: a cross-table lateral view, an anteroposterior view, and an open-mouth view to help visualize the odontoid process.[2]

DISABILITY

Perform a quick assessment of neurologic function at the end of the primary survey, and repeat during the secondary survey to monitor for changes in the child's neurologic status. Causes of decreased level of consciousness in injured children include traumatic brain injury (TBI), hypoxemia, and poor cerebral perfusion. The latter two can exacerbate a TBI and result in secondary brain injury. Assessment and management of the head-injured child is discussed in a separate article in this issue of the journal.

PRIMARY SURVEY IMAGING

Some ATCs have employed whole-body CT (WBCT) during the primary survey instead of traditional radiographs. Kanz *et al*. introduced the term "focused assessment with computed tomography in trauma" (FACTT).[14] This imaging modality has been shown to shorten the time taken to make a definitive diagnosis.[14,15] The potential risk of malignancy caused by radiation from CT in children needs to be weighed up against the benefit of avoiding fatality from missed injuries.[16-18]

A digital trauma X-ray device known as the "Lodox Statscan" (Statscan Critical Imaging System, Lodox Systems [Pty] Ltd, Johannesburg, South Africa) provides a full-body anterior and lateral view based on enhanced linear slot-scanning technology. The same amount of information as a traditional ATLS® trauma series (C-spine, chest and pelvis) is obtained in less time with less radiation dose.[19] "The full-body radiograph may allow CT to be used more selectively and to reduce overall radiation."[20]

INTRATHORACIC INJURIES

The vast majority of serious chest injuries in children are the result of blunt trauma. Most are the result of car and bicycle crashes. The presence of significant chest injury enhances the potential for multisystem trauma mortality by a factor of 10.[2] Life-threatening thoracic injuries, such as airway obstruction, tension pneumothorax, massive hemothorax, and cardiac tamponade, are identified and treated during the primary survey.

The compliance of the child's rib cage allows significant injury to occur with few obvious external signs of trauma. Energy is transmitted to the thoracic contents, and pulmonary contusions and hematomas are relatively more common, noted in more than 60% of children with severe thoracic injury.[21] Because children have high oxygen consumption and low functional residual capacity, pulmonary contusions can result in severe hypoxemia, which may be refractory to oxygen therapy.

Commotio cordis is a disorder described in the pediatric population that results from a sudden impact to the anterior chest wall (such as a baseball injury) that causes cessation of normal cardiac function.[22,23] The child may have an immediate dysrhythmia or ventricular fibrillation that is refractory to resuscitation efforts.

INTRA-ABDOMINAL INJURIES

Abdominal trauma is the most common cause of unrecognized fatal injury in children. Blunt trauma related to MVCs causes more than 50% of the abdominal injuries in children and is also the most lethal. Bicycle handlebars are a common cause of blunt abdominal trauma.[24] Children have proportionally larger solid organs, less subcutaneous fat, and less protective abdominal musculature than adults. They suffer relatively more solid organ injury from both blunt and penetrating mechanisms.[2] Approximately one-third of children with major trauma will have significant intra-peritoneal injuries.[1]

The physical examination of the child's abdomen begins during the secondary survey. The stomach and bladder need to be decompressed, and abrasions and contusions of the torso need to be looked for. Persistent, gentle palpation of the abdomen may find significant tenderness if the level of consciousness is not impaired and there are no distracting injuries.

Focused abdominal sonography for trauma (FAST) has become a useful part of the initial trauma evaluation. It can be done in 3 min, is noninvasive, portable, can be performed during the resuscitation, and does not offer a radiation dose.[25] FAST evaluates for free intra-peritoneal fluid, which often coincides with intra-abdominal injury. A recently published meta-analysis included 25 studies on the use of abdominal ultrasound in the pediatric blunt trauma. Ultrasound had a sensitivity of 80% (76-84%) and a specificity of 96% (95-97%) for the identification of hemoperitoneum.[26]

Computed tomography (CT) remains the gold standard for diagnosing abdominal injuries. Although CT detects most abdominal injuries, only 5% of patients with abnormal findings on CT go to surgery for treatment of these injuries.[27] The success rate of non-operative management is high (95%) in children with solid organ injuries.[28] These patients are managed with serial abdominal examinations and hematocrits, bed rest, and may need repeated imaging studies such as CT scans or ultrasounds. It is prudent to type and crossmatch blood products for all trauma patients with blunt solid organ injuries, as sudden, unexpected deterioration due to internal hemorrhage is a possibility.

Diagnostic peritoneal lavage (DPL) can rapidly determine or exclude the presence of intraperitoneal hemorrhage. This diagnostic tool is used less often with the increasing use of FAST and abdominal CT scan in many trauma centers. DPL is most useful in patients who are hemodynamically unstable, those with an unreliable physical examination, especially when CT or ultrasonography detects minimal fluid or when the patient manifests fever, peritonitis, or falling hematocrit that cannot be otherwise explained. DPL can also be used to evaluate abdominal trauma in children who require urgent surgical intervention for associated extra-abdominal injuries, such as craniotomy. A negative result on DPL lets the clinician proceed with management of other injuries and avoids unnecessary laparotomy for the patient.

PAIN ASSESSMENT

Children cry for a variety of reasons, and it is important to ascertain whether they are in pain. As obvious as it may sound, the injured child who appears to be in pain most likely is in pain. The trauma physician must determine the intensity, cause, and nature of the pain before initiating therapy. There are a number of pain assessment tools available to measure pain in children.[29] The Alder Hey Triage Pain Score (AHTPS) was developed and validated for children aged 0−16 years at triage in an ED setting.[30] In the pre-verbal child, behavioral scores such as the FLACC score can give an objective, reproducible pain score.[31] Children as young as 3 can use cartoon faces[32] to indicate their pain intensity. From the age of about 5, children can use a visual analog score (VAS) and from about 8 they can reliably give a verbal rating score (VRS).[33]

AIRWAY MANAGEMENT INCLUDING C-SPINE STABILIZATION

If the airway is obstructed, inspect the mouth for a foreign body and remove it, but do not perform a blind finger sweep, which may push it further into the airway. Suction to clear blood, secretions, or vomitus. Perform an airway-opening maneuver: jaw thrust or chin lift. If there is any possibility of C-spine injury, do not perform a head tilt maneuver. If the child is unconscious, an oral airway may be required to lift the soft palate away from the base of the tongue. Bear in mind that inserting an oral airway into a semi-conscious child's mouth may cause gagging and vomiting. Administer high-flow oxygen via a non-rebreathing face mask with an oxygen reservoir.

If the child is apneic or is making poor respiratory effort, assisted ventilation is required. When properly performed, bag-valve-mask (BVM) ventilation for a short period of time is as effective as ventilation via an ETT, and may be safer. A controlled trial of BVM versus ETT ventilation in an urban pre-hospital setting found no significant difference in survival or in the rate of achieving a good neurological outcome between the BVM group and the ETT group.[34]

If an airway device has been placed prior to arrival in the trauma bay, the emergency department (ED) physician and/or anesthesiologist should not assume that it is the appropriate device, or that it has been correctly placed. The receiving team needs to be familiar with airway devices used by pre-hospital personnel, as they may differ from those used in the hospital. Capnography is the gold standard to confirm ventilation of the lungs. Capnography does not rule out mainstem bronchial intubation, however. Also, an ETT which is dislodged just proximal to the vocal cords could result in a waveform on the capnograph.

If intubation is necessary, a quick assessment of the airway should be made prior to induction of anesthesia and administration of a neuromuscular blocking drug. A back-up plan should be in place in anticipation of a difficult or failed intubation. A gum elastic bougie of appropriate size should be immediately available. A video laryngoscope, fiberoptic scope or LMA Fastrach™ should also be kept handy.

Presume that the child's C-spine is injured until proven otherwise, especially in a child with a head injury. Techniques of immobilizing the C-spine include towel rolls, cervical collar, spinal board, and tape. Manual inline stabilization (MILS) of the C-spine is essential for intubation.

MANAGEMENT OF BREATHING, VENTILATION, AND OXYGENATION

For non-intubated patients arriving to the emergency room (ER), it is vital to assess, re-assess, and keep re-assessing ABCs for adequacy until the patient is transferred to the definitive care place (ICU or floor or the operating room). Pediatric victims of polytrauma have near-normal vital signs even in the presence of significant blood loss, and can deteriorate rapidly. These children should be monitored with extra vigilance during transport to the CT scanner, in the CT scanner, and in the emergency room.

Patients who arrive to the ER intubated should be monitored for existing or developing complications such as barotrauma or endobronchial intubation, in addition to ensuring that their oxygenation and ventilation is adequate.

If the child has confirmed or suspected head injury, and if ICP is monitored, mild hyperventilation may be needed for refractory increases in ICP. Prophylactic hyperventilation is not recommended, and may be harmful, by causing cerebral vasoconstriction and ischemia.

MANAGEMENT OF PAIN

Pain has, historically, been undertreated in patients presenting to the ED.[35] This problem may be even greater in young pre-verbal injured children than in older children.[36] Many physicians fear that administering opioids will mask symptoms of progressing injury. A recent meta-analysis found that the administration of opioids did not result in significant increase in management errors in patients presenting to the ED with abdominal pain. The three pediatric trials that were included actually showed a non-significant absolute decrease in management errors.[37]

Another reason for withholding or under-dosing opioids is fear of side effects such as respiratory depression, hypotension, nausea and vomiting, and drowsiness. These side effects can be reduced or avoided by employing regional anesthesia techniques. Epidurals, paravertebral blocks,[38-40] or even simple intercostal nerve blocks[41] can be extremely useful for children with rib fractures or flail chest. Femoral nerve block or fascia iliaca block can easily be performed in the ED to relieve pain from femoral fracture rapidly and effectively. While femoral nerve block is common in some countries (Australia[42] and UK[43]), it is uncommon in the emergency setting in North America.

If a regional anesthetic technique is not possible, a multimodal analgesic technique combining acetaminophen and NSAIDs reduces the dose of opioids required to treat pain. In the child who is NPO, IV acetaminophen and IV ketorolac can be given. IV patient-controlled analgesia (PCA) can be used in children above the age of about 5 years, and it allows the child to titrate opioid boluses according to the pain that they are experiencing.

PREVENTION OF HYPOTHERMIA

All victims of major trauma should be considered to be at risk for hypothermia. Children are more prone to develop hypothermia than adults. Hypothermia can lead to arrhythmias, coagulation abnormalities, and acidosis. The latter two, along with hypothermia, constitute "the triad of death" in trauma patients. An initial core temperature measurement (oral, rectal, or bladder) should be done as a part of the primary survey.

The pediatric trauma room in the ED should be maintained at >80° F. Passive rewarming, i.e. removal of wet clothing/linen and coverage with warm blankets, along with minimizing exposure for diagnostic procedures, should be undertaken in all children. The child's head should be covered with a reflective hat. All IV fluids and blood products should be warmed using fluid warmers. Active external rewarming with a convective air blanket (e.g. Bair Hugger®) should be considered in all children with a core temperature of <36°C.

Appendix 1: Pain scales commonly used in children of various age groups

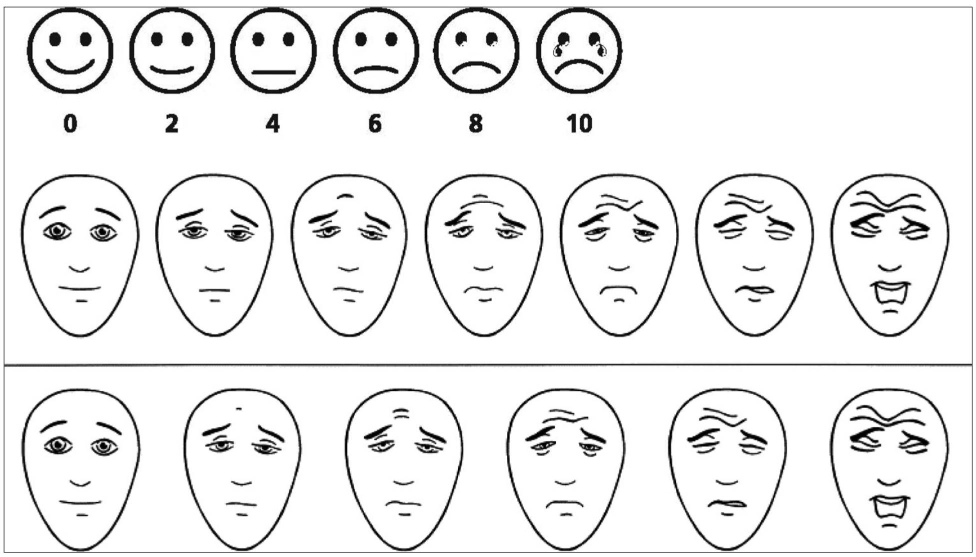
Alder hey triage pain score[30]

Response	Score 0	Score 1	Score 2
Cry or voice	No complaint/cry Normal conversation	Consolable Not talking, negative	Inconsolable Complaining of pain
Facial expression	Normal	Short grimace <50% of time	Long grimace >50% of time
Posture	Normal	Touching/rubbing/sparing	Defensive/tense
Movement	Normal	Reduced or restless	Immobile or thrashing
Color	Normal	Pale	Very pale/''green''

FLACC core[31]

Response	Score 1	Score 2	Score 3
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, disinterested	Frequent to constant quivering chin, clenched jaw
Legs	Normal position or relaxed	Uneasy, restless, tense	Kicking, or legs drawn up
Activity	Lying quietly, normal position, moves easily	Squirming, shifting back and forth, tense	Arched, rigid or jerking
Cry	No cry (awake or asleep)	Moans or whimpers; occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging or being talked to, distractible	Difficult to console or comfort

Faces pain scales



PSYCHOSOCIAL SUPPORT FOR THE CHILD AND FAMILY

Experiences with accidents, injuries, physical abuse, or hospitalization can leave a lasting impact on some children's minds. While some are able to cope with the experience and move on, some others and their families may benefit from psychosocial support and intervention.

Medical facilities dealing with traumatized children should have a multidisciplinary team, comprised of social workers, psychiatrists, psychologists, etc., to help patients and their families deal with the after-effects of a traumatic experience.

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