Pediatric Section

Management of a child with multiple trauma

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Introduction
Trauma is a preventable pediatric disease. It is the leading cause of death in children over one year of age. Two-thirds of pediatric major trauma victims have an isolated head injury. Head injury is the most common cause of death due to multiple trauma in pediatrics.1 Pre-hospital trauma care ideally involves a fast response transport system where an emergency medical technician (paramedic), trained in resuscitation and stabilization of the injured child goes to the scene of the accident, and carries out the task of ongoing trauma care until arrival to the emergency department. In Delhi CATS (Centralized accident and trauma service) has been in place to transport trauma victims to the nearest tertiary care center. Unfortunately due to insufficient ambulances, lack of trained personal, traffic congestion and a lack of organized air transport system to transport a trauma victim, this system has a lot of scope for improvement. Private ambulance companies as well as private hospitals are able to provide somewhat more efficient dispatch system as well as trained personnel, however the problem of traffic congestion and lack of uniform standards of many such private transport systems remain.

Most of the time a trauma victim is brought to the emergency room (ER)/Casualty by private vehicle by the relatives, the police, or by standers in the event of an ambulance delay, which is a frequent occurrence. This review is intended to familiarize the pediatrician, the pediatric emergency physician and the pediatric intensivist with a gross overview of protocolized care of a child with multiple trauma in the ER and in the ICU.

Emergency room management protocol
Proper care of the young child with multiple trauma demands a systematic approach that has been rehearsed - mentally and physically - so often by all members of the pediatric trauma team that it has to become a automatic reaction. This plan includes, but is not limited to, an understanding of the pediatric airway, control of hemorrhage and principles of resuscitation. Only following the stabilization of the child can an assessment of, the extent of injuries be undertaken and priorities in definitive treatment be established.

Centers that lack this disciplined protocol can provide, on occasion, adequate care to the severely injured child, but the quality of that care will be variable and often below that which is considered state of the art.

Priorities

Primary survey
Involves a quick survey from head to toe to prioritize management of life threatening issues.2

The ABC’s of life-saving care are now well known:
A. Airway assessment and management, with cervical spine immobilization
B. Breathing and provision of essential alveolar ventilation
C. Circulation with prompt control/arrest of hemorrhage
D. Disability, with a rapid neurological examination
E. Exposure of entire child for detection, evaluation and stabilization/treatment of injuries.

This easily recalled mnemonic is aimed at the immediate identification and treatment of those specific injuries capable of producing death, i.e. airway obstruction, tension pneumothorax, pericardial tamponade and shock from blood loss.
Following the ABC’s, in sequence, comes treatment of the greatest threats to life in the order in which these threats kill. As an example, airway obstruction is more rapidly fatal than is tension pneumothorax, which is more quickly lethal than shock. While space does not allow a detailed description of specific injuries to organ systems, the principles of initial management will be briefly discussed.

A. Airway

The relatively large tongue of children tends to fall posterior and obstruct the airway, particularly in unconscious patients. This obstruction is accentuated by either excessive flexion or extension of the neck and minimized by adopting the sniffing (midflexion) position. This is achieved by placing a folded towel beneath the occiput, causing slight flexion of the lower, and minimal extension of the upper, cervical spine. Jaw thrust can be used as airway opening maneuver instead of head tilt and chin lift in patients with possible cervical injury, which should be presumed on all trauma victims. Foreign matter in the oral cavity loose teeth, blood, mucus, roadside debris, etc. - can fatally obstruct and is removed best by a finger sweep and large bore suction device. Blind finger sweep, however, is not recommended as it can push the foreign body deeper into the pharynx. Remaining foreign matter out of reach may be removed using a Magill's forceps under vision.

Oxygen is supplied by the most readily available means. Mouth to mouth resuscitation, or air from a self-inflating bag are acceptable techniques until oxygen by mask is available. A plastic oral airway, placed to hold the tongue forward, is appropriate only if the child accepts it.

Should endotracheal intubation be required in emergency situations, this should be performed with an uncuffed tube by the oral route as a rapid sequence intubation (RSI) with presumed full stomach and high risk of aspiration of gastric contents.

Preoxygenation, cricoid pressure, intravenous induction followed by short acting muscle relaxant and oral intubation are essential steps of RSI. The internal diameter of the tube is age-dependent and, in millimeters, is \((4.0 + \text{age in years divided by 4})\). The distance to which the tube is inserted past the lips, in centimeters, is \((11-12 + \text{age in years})\), though ultimate tube position should always be confirmed by clinical exam (bilateral chest excursions and breath sounds) and a chest radiograph.

B. Breathing

Mechanical ventilation will be a mainstay of therapy for, most children who suffer severe multiple trauma. A decreased lung compliance can be a major problem, particularly in those patients with extensive thoracic and/or abdominal trauma.

Appropriate ventilation can generally be initiated with an initial tidal volume of 10-15 ml/kg, 3-5 cm H2O of positive end-expiratory pressure (PEEP). Ventilator rates in the infant, toddler and older child can be started at 30, 25 and 20 inspirations per minute, respectively. Initial inspired \(\text{O}_2\) concentration should always be 100%. A variety of factors will determine changes in ventilator settings, but in the final analysis, repeated arterial blood gas determinations and oxygen saturation are the major parameters dictating ventilator therapy. pH modifiers (\(\text{NaHCO}_3\)) play a role in correcting acidosis, but are generally withheld until the \(\text{PaCO}_2\) has been controlled and adequate fluid resuscitation has been performed.

Circulation

After the child's airway is secured and ventilation established, Hemodynamic stability becomes the major consideration. In blunt, as well as penetrating trauma, the more common urgent problems are control of ongoing hemorrhage and treatment of shock. Much less common, though equally critical, are cardiac tamponade and cardiac arrest.

Direct pressure applied to bleeding wounds remains the safest method to control external hemorrhage. Torrential hemorrhage from a child’s scalp, however, frequently overlies compound or depressed skull fractures with disruption of intracranial veins. Direct pressure on these sites may be impractical. Elevation of the head several inches above the level of the heart will minimize blood loss. The clamping of spurting vessels, with hemostats (artery forceps) should generally be avoided, particularly in deep, poorly visualized wounds. Important nerves closely accompany most major arteries, and injudicious clamping may irreparably damage these. Tourniquets or pressure dressings may be utilized for the temporary control of rapidly bleeding extremity wounds. Blood pressure cuffs are preferable to narrow; make shift
tourniquets as they deliver a quantifiable pressure over a broad area. The pressure applied with a tourniquet must exceed systolic blood pressure or it is worse than no tourniquet at all; if too loose, arterial blood is shed and venous blood cannot return to the body.

In any case, any tourniquet should be replaced as quickly as possible with a sterile pressure dressing.

In many areas, tourniquets have been replaced by the pre-hospital application of the military anti-shock trouser (MAST). While there is controversy regarding their use in pediatrics, the MAST garment is of particular value in patients with unstable pelvic fractures and/or extensive intra-abdominal injuries. Hemorrhage is reduced and circulation to the heart, lungs and brain is assisted.4,5

Shock in the pediatric patient following major injury is practically always due to blood loss.

Neurogenic, cardiogenic and septic shock do occur in this setting, but they are rare and precise differentiation is unnecessary initially since initial management differs little, if at all, with that of hypovolemic shock.

Clinically, shock is characterized by tachycardia, cool, pale or mottled extremities, irritability or an obtunded sensorium. Oliguria is a fairly constant finding unless head injury has produced diabetes insipidus. Hypotension is a late manifestation of hypovolemia and may only appear after loss of 25% of circulating blood volume due to compensatory mechanisms (primarily release of endogenous catecholamines) present during the early phase of blood loss. A normal blood pressure may fool the clinician into a false sense of security, so meticulous attention to the more subtle manifestations of shock in pediatric patients is essential, such as tachycardia, poor capillary refill, cool extremities, mental status and urine output.

Vascular access is initially attempted by percutaneous insertion technique at the antecubital vein at the ankle, traditionally the favored sites. An upper extremity catheter is preferred if the potential for serious abdominal injury exists. If patient movement or vasoconstriction makes 2 or 3 attempts unsuccessful, intraosseous access should be promptly undertaken. Expertise in this fairly simple maneuver is an essential skill for anyone involved in the care of traumatized children. The placement of a central venous catheter for the acute fluid resuscitation of a traumatized child can lead to wastage of time. Such catheters are appropriate only subsequently in the pediatric intensive care unit for venous pressure monitoring, and/or provision of parenteral nutrition centrally.

**Introsseous access**

Increasing utilization of Intraosseous infusions6 by prehospital personnel has made time consuming vascular access procedures in the emergency department less necessary. Other advantages of this technique include: (i) many easily accessible routes (tibia, femur, ileum or sternum); (ii) very little skill is required to perform the procedure, and (iii) the complication rate is exceedingly low. While this modality should be considered for infusion of fluid, blood and most drugs in the initial minutes of resuscitation, conversion to a secure intravenous catheter should be performed when this can be accomplished.

**Choice of resuscitation fluid**

Debate continues to rage over the ideal initial resuscitation fluid, though most centres utilize Ringer’s lactate, normal saline (crystalloids).7 All patients are given two to three rapid intravenous fluid boluses of 20 ml/kg each. Further management is dictated by the hemodynamic response, or lack of response to this initial infusion. If blood pressure returns to normal, fluid infusion is continued at a maintenance rate. If shock persists after half of the blood volume has been replaced by crystalloid (two to three boluses), blood transfusion is necessary. Usually 10-20 ml/kg of packed red blood cell transfusion is adequate. Ongoing transfusion requirements generally indicate the need for operative intervention.

**Secondary survey**

This survey is performed after life threatening injuries have been addressed.

Secondary survey involves detection of all injuries.

Following is a discussion of protocol of management of common injuries in a multiple trauma victim. Head injury has been omitted from this discussion as it is a separate topic. Specific bony injuries are beyond the scope of this discussion. This description of protocols
will concentrate on major thoracic and abdominal injuries.

**Thoracic injuries**

Significant pulmonary parenchymal, cardiac or great vessel injury may result from both penetrating and blunt trauma. In all cases, examination includes inspection of position of trachea, symmetric movement of chest, palpation of fractures and subcutaneous emphysema and auscultation for quality and location of breath sounds. Outcome of this process is reflected in the arterial blood gas analysis or by monitoring of both oxygen saturation and end tidal carbon dioxide.

**Lacerations** that do not communicate with the pleural cavity are handled in the usual fashion. Externally visible lung constitutes open pneumothorax and is treated with application of partially occlusive dressing and immediate tube thoracotomy.

**Tracheobronchial or esophageal injury** may result in extra anatomic air, as may cervical, facial and retroperitoneal injuries. A massive air leak, failure of lungs to re expand after placement of chest tube should raise suspicion of tracheobronchial injury. Prompt broncoscopy is performed before definitive repair. Esophagoscopy or Gastrograffin swallow may exclude Esophageal injury. Upper tracheal injuries are approached via median sternotomy. Distal tracheal, bronchial and esophageal injuries are associated with significant morbidity and mortality.

**Rib fractures** trigger a progression of pain, splinting, atelectasis and hypoxemia. It is important to prevent this progression through appropriate use of adequate analgesia and pulmonary toilet. Parenteral narcotics, local anesthesia and epidural delivery of narcotics must be considered in appropriate cases. Flail chest arises when >3 ribs are fractured in two or more places gives rise to paradoxical chest wall motion with respiration.

**Pulmonary contusion** frequently coexists with rib fractures, flail chest and penetrating pulmonary parenchymal injury. Contused regions are perfused but hypoventilated causing severe hypoxemia. Placing injured side up promotes perfusion to the better ventilated down side lung. The most severe contusions require admission to the PICU and expert critical care. These patients have severe hypoxemia with or without air leak syndromes (pneumothorax) and will require chest tubes, low tidal volume ventilation and inotropic support until improvement in lung condition occurs. Airway obstruction with blood clot is a frequent risk alleviated by keeping the endotracheal tube open by humidification and suctioning.

**Hemothorax** arises most commonly from penetrating injuries and requires a chest tube in most circumstances. Retained hemothorax is a significant risk factor for post traumatic emphysema and fibrothorax. For many injuries, thoracostomy is a sufficient surgical intervention. Many guidelines for operative intervention based on the amount of initial drainage and ongoing hemorrhage from the chest tube have been proposed. These guidelines should be individualized.

**Chest wall soft tissue loss** may be encountered occasionally in the trauma setting. The chest wall can be closed initially with PTFE mesh; however complex flap or prospective closure is often required for long term coverage.

**Cardiac and Great vessel injury** is common in both penetrating and blunt thoracic trauma. Widening of the heart shadow on an chest X-ray and a focused Ultrasound examination for trauma (FAST) of the chest provides early evidence of cardiac tamponade and mediastinal injury. Auscultation of diminished heart sounds in association with shock (Beck’s trail) provides a late diagnostic clue that a cardiac injury with pericardial tamponade has occurred. Breath sounds must be auscultated because tension pneumothorax has a similar picture. Echocardiography must be performed in stable patients to rule out underlying cardiac injury. Pericardio centesis has little role in diagnosis or management of cardiac injury or tamponade. Tamponade once diagnosed needs to be relieved immediately by pericardiocentesis.

**Thoracic Great vessel injury** most commonly results from penetrating injury and presents with profound shock and associated hemothorax. Occasionally, cardiac tamponade may result from proximal aortic or venacaval injury. These patients often require thoracic surgeon to operate without the benefit of preoperative vascular diagnostic studies.

**Blunt Thoracic Trauma** frequently results in serious
cardiac or great vessel injury. Injuries associated with rapid deceleration can cause aortic rupture, typically when ligamentum arteriosum inserts just below the origin of the left subclavian artery. When there is suspicion of Aortic transaction based on previous radiographic procedures, immediate aortography is indicated. If it demonstrate an aortic tear, urgent surgical repair is mandatory.

**Abdominal Trauma**

The abdomen extends from the diaphragm to the pelvic floor. The anterior surface marking of the abdomen therefore extends from the nipples to the inguinal creases. The purpose of secondary survey is to determine whether an abdominal injury has occurred rather than what the abdominal injury is. Local wound exploration, in patients with penetrating abdominal injury, will tell whether peritoneum is violated in an otherwise stable patient.

**Abdominal ultrasonography, CT scan and laparoscopy** have been proposed as useful adjuncts to evaluate and manage patients with penetrating and blunt abdominal injuries. With the nearly universal utilization of abdominal CT scanning in pediatric trauma patients with potential intra-abdominal injuries, the indications for abdominal paracentesis have been greatly reduced. CT scan of the abdomen certainly plays no role in the neurologically intact child without significant abdominal findings, nor is it of value when abdominal operation is required on clinical findings. Moreover, the presence of blood within the peritoneal cavity is not considered an absolute indication for laparotomy in children whose solid organ injuries may be well-treated by non-operative regimens. It is, therefore, reserved for those patients with head injuries who are difficult to examine, uncooperative or when an abdominal CT scan cannot (or should not) be performed.

**Diaphragmatic injuries** are being increasingly recognized in cases of blunt trauma in which evident elevation of intra abdominal pressure results in diaphragmatic rupture. All such injuries must be recognized to prevent long term complications of diaphragmatic hernia.

**Simple lacerations of abdominal esophagus** can be repaired, after mobilization of left lobe of liver, using fine absorbable suture taking care not to create a surgical stricture. Stomach may be used to buttress a repair.

Simple lacerations of stomach are generally repaired in one or two layers. Massively devitalizing injuries may require formal resection with restoration of continuity via a gastroenterostomy. Vagotomy is helpful in reducing the risk of marginal ulcer.

**Minor blunt hepatic injuries** require no therapy. Even major blunt hepatic injuries that are contained within Glissons capsule may be treated expectantly and followed serially. Those with increasing pain or ongoing blood loss may be treated with embolotherapy with laparotomy reserved for patients who fail this modality.

**Violation of liver capsule** with associated bleeding in blunt hepatic trauma requires surgical intervention. Penetrating injuries should likewise be explored. Management of major hepatic venous or juxta or retrohepatic venacaval injuries, is one of the most challenging issue faced by the trauma surgeon. These patients have exsanguinating hemorrhage requiring placement of atrio caval shunt.

**Gall bladder injuries** frequently coexist with hepatic, portal triad and pancreatoduodenal injuries and are managed by cholecystectomy.

**Injuries of enterohepatic biliary** system are apparent at the time of laparotomy but may be confirmed with intraoperative cholangiography. Repair is done over a T-tube. Roux-en-Y choledochojejunostomy is best for segmental loss.

**Duodenal injuries** with devastating GI and abdominal vascular injuries represent a diagnostic and therapeutic challenge. In exploration, complete mobilization of duodenum is performed and repair done in two layers with closed suction drains placed around the leak. Pancreatoduodenectomy is reserved for the most complex injuries involving the duodenum including duodenal devascularization and combined injuries including pancreatic head and distal common bile duct.

**Blunt Splenic injuries** can often be managed without surgery especially in children who are hemodynamically stable and injury that can be demonstrated on CT scan. Splenectomy is indicated for progressive clinical dete-
Prioritization, failing hemotasis or radiologic progression of injury.

**Small intestinal injury** may be repaired primarily or may require segmental resection and anastomosis. Mesenteric defects should be closed.

**Small stab wounds** in colon may be closed in two layers using absorbable sutures. A large injury may require resection the injured segment with end colostomy, Hartmann's pouch or mucus fistula.

**Rectal injuries** most often result from penetrating wounds and are often associated with genitourinary / pelvic injury. They are managed by construction of diverting sigmoid colostomy, rectal washout and presacral drains.

**Pediatric intensive care unit (PICU) management protocol**

Trauma is a systemic disease. In fact, seriously injured children in the PICU are multisystem disease patients. A child whose mechanism of injury (particularly when as a result of blunt forces) is of sufficient severity to warrant ICU care is quite likely to develop alterations in physiology of other organ systems not initially traumatized. As an example, a child with an isolated severe closed head injury may subsequently develop alterations in cardiovascular, respiratory, gastrointestinal and/or renal function. These can occur early or late following trauma, so a systems approach to the daily care of the patient is a clear necessity. This can only be effectively provided in the environment of the PICU, where concentrated monitoring equipment and capabilities can generate a sophisticated physiologic profile on virtually any patient.

The overwhelming majority of pediatric trauma patients in the PICU do not require a major surgical procedure. In spite of this, unreported children will require at least the same degree of support and monitoring, and frequently more, since they furnish a larger unknown element regarding anatomic alterations, than in those patients whose precise injuries were documented (and repaired) by operative intervention. It is a caveat among pediatric surgeons that trauma may not, in any given patient, require operative care, it does, in all patients, require surgical care. Serious injuries can and do escape initial detection and ongoing surveillance, and frequently primary care responsibilities, by a surgeon is essential.

Nonetheless, optimum management is provided by a team approach, necessitated by the multidisciplinarian problems that overlap consistently in pediatric trauma patients. Pediatric intensivists, surgeons and pediatricians must communicate at least daily, and ready access to consultation from other pediatric medical and surgical subspecialists is essential to support any PICU that regularly cares for traumatized infants and children. The PICU nurses should be included in all major discussions. They spend more time with the patient and family than any physician possibly could, and their input on the patient’s status and treatment must be actively sought.

Visitors to a modern PICU are invariably impressed by the amount of monitoring equipment available. As a result of this technology, it is easy and tempting to spend the majority of time on trauma rounds reviewing the “numbers” generated by this expensive gadgetry, at the expense of hands-on time with the child. This is an unfortunate tendency. Monitors should complement and even enhance the physical examination of the small child, not replace it.

**PICU Monitoring of a trauma patient**

**Frequent clinical examination is the most important human monitoring.**

Some of the specific monitoring utilized in the acute care of the traumatized child include, by system:

**Cardiovascular**
- Vital signs
- Electrocardiogram (cardiorespiratory monitor)
- Noninvasive blood pressure(NIBP)
- Continuous arterial blood pressure
- Central venous pressure

**Respiratory**
- Ventilator alarms
- Ventilator graphics
- Pulse oximetry
- End tidal C02 monitoring

**Central Nervous system**
- Intracranial pressure monitoring
- Psychological/mental status evaluation
Coagulation
Clotting parameters
Transfusion requirement

Other systems that demand constant monitoring include: renal status, metabolic and nutritional status, infection status and dermatologic manifestations of trauma complications.

The pediatric surgeon will also pay particular attention to the changes in abdominal girth, volume of drainage from chest tubes and other drains, and steep drops in hemoglobin and hematocrit levels. A high index of suspicion should be kept for the development of thoracoabdominal abscess, particularly in the context of penetrating trauma and/or postoperative patients. Though children are most impressive in their recuperative powers, the recovery of a child with massive trauma tends to be slow and gradual, while deterioration may be abrupt and rapid. Anticipation of the potential complications with any given injury, readiness for any unsuspected sequelae or previously unrecognized diagnosis, and a willingness to continually reassess the patient and his or her progress must accompany our increasing reliance upon (and fascination with) machines and tests that interfaces intimately with the small child.

Summary
Successful management of a child with multiple trauma involves a well planned organized coordinated team effort on the part of critical care transport system personnel, pediatric emergency physician in casualty, pediatric surgeon, pediatric intensivist, pediatric neurosurgeon and many other subspecialists. Pediatric emergency physician should take charge of performing primary survey and initial resuscitation. Pediatric intensivist should take charge of ongoing medical management in the picu in the preoperative or postoperative period. Pediatric surgeon should take overall charge of investigations to detect various injuries and coordinating surgical repair in order of priority by himself or involving various surgical specialists such as neurosurgeon, cardiothoracic surgeon, plastic surgeon, orthopedic surgeon as deemed necessary.

References