Applying the 3 P’s to Pediatric Resuscitation—Planning, Preparation and Persistence

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Objectives
At the conclusion of this learning session, the learner will be able to:
• Develop a management plan for commonly diagnosed traumatic injuries in children
• Analyze emerging research, developing standards and learning experiences to increase quality of pediatric resuscitation

Purpose
• Trauma is the leading cause of death in children age 19 and under
• Blunt trauma is the most common mechanism of injury (falls, MVC)
• 25% of all traumatic injuries occur in children
• Critically ill children have better outcomes when treated in pediatric trauma centers (Manual of Pediatric Trauma)
Dr. James Styner – 1976 crash

“When I can provide better care in the field with limited resources than my children and I received at the primary facility, there is something wrong with the system and the system has to be changed”

Committee of the Future of Emergency Care in the United States Health System 2007

- Examine the full scope of emergency care
  - 3 reports
- Emergency Care for Children: Growing Pains
  - Identified needs in pediatric trauma care
  - Noted that issues affecting the emergency care system have a greater impact on the outcomes of critically ill pediatric patients.

North Carolina study (Hunt, 2006)

- 35 Emergency Departments
- Failure to stabilize seriously injured children during trauma simulations
  - Accurate estimation of patient weight - 49%
  - Treatment of severe hypoglycemia - 97%
  - Treatment of hypothermia - 97%
  - Proper administration of IV fluid boluses - 89%

CSHCN at risk for suboptimal care during emergent event - even with advanced training

- Occult medical problem
- Recognizable problem with atypical management
- Unknown baseline status with known medical condition
- Rare condition
- Technology-dependent child
- Inaccurate medication dosing/delivery

(Sacchetti, et al., 2000)
• Pediatric Medication Safety in the Emergency Department (AAP, 2018)
  - Community EDs and inpatient units
    • 28.3 million - 89% seen in non-pediatric hospitals, 4% critical or require admission [H-CUP, 2010]
    • Errors 10-31% in Pediatric dedicated ED, 39% in Community ED (AAP, 2018)
  - EMS providers
    • 10% pediatric, 1% critical
    • Errors 34.7%
  - Rural vs urban
    • 8% vs 92%

Medication errors 3 times the rate in adult patients.

Think about that…

Purpose.

Planning and Preparation

AAP Policy Statement: Pediatric Medication Safety in the Emergency Department recommendations:

• Up to date, readily accessible reference materials
• Use of length-based dosing tools when scale not available or use not feasible
• Weights measured and recorded only in kilograms
• Provide recommended pre-calculated doses with standard concentrations
• Root Cause of Errors in Pre-hospital Simulated Pediatric Emergency (Lammers, et al. 2012)
  • Active cognitive, procedural, affective, teamwork and latent errors
  • Knowledge and skill retention by EMS correlated by frequency of use
  • 60% error rate for Versed and 47% error rate for Valium for seizures
  • Error producing conditions
    • Equipment not carried to patient, peds bags locked, lack of familiarity with equipment

• Simulation valuable for identifying unanticipated errors and previously unrecognized, error-producing conditions

• Reducing Cognitive Load with Resuscitation Aids (Luten, et al. 2002)
  – Two important practical considerations in a resuscitative process:
    • Delay in the time needed to implement a given action or prolonged implementation time
      – Prolonged and more error prone in peds resuscitation due to multiple age and size related factors which must be addressed from evaluation through completed action
    • Error in decision making as a result of, or in part from, suboptimal or inadequate critical thinking time.

• Cognitive load is an important and critical feature of the pediatric resuscitation process.
• Cognitive load depends on the degree of uncertainty in the process.
• The degree of uncertainty determines the number of decisions that will need to be made.
• The more complex, non-automatic decisions in the process, the greater the cognitive load.
• Increased cognitive loading means increased error.
• In the setting of pediatric resuscitation, size-related variables introduce the need for non-automatic activities and decisions, thereby increasing the cognitive load. The size-related variables are unique to the resuscitation of children.
• These nonautomatic, size-related decisions can be relegated to an automatic level using resuscitation aids.

Recommendations:
• Up to date, readily accessible reference materials
• Use of length-based dosing tools when scale not available or use not feasible
• Weights measured and recorded only in kilograms
• Provide recommended pre-calculated doses with standard concentrations
• Create and integrate a dedicated pediatric medication safety curriculum into training programs for all providers
Recommendations:
- Implement and support the availability of pharmacists in the ED
- Develop tools for competency assessment
- Pediatric equipment available for patients and for staff to familiarize themselves with
- Routine simulation to identify obstacles for successful resuscitation

**Patience and Persistence**

What makes the pediatric patient different in trauma care?
Patience to watch for subtle differences and changes:

- Deceleration mechanisms can cause massive and fatal c-spine injuries
- Hypothermia develops frequently
- Different physiological response to injury
- Vast compensatory mechanisms followed by rapid deterioration
  - Smaller blood volume
  - Smaller airway
  - Less energy reserves to maintain adequate ventilation

• Different patterns of injury
  - Relatively large head, flexible bones and ligaments
• Injuries to deep soft tissues may be very significant in the absence of fractures
• Use the mechanism of injury to raise questions of internal injuries

Patience and persistence to determine injuries...

- Act younger than their age in the event of trauma and separation from parents
- Unable to localize pain until mid-school age years
- With a pre-verbal patient, clinical exam is virtually all we have to rely upon
- Evaluate response to strangers, ability to focus/track

PATIENCE. PERSISTENCE.
Airway with C-spine control

Assume cervical spine injury
- Improperly fitting collar worse than no collar!!

Airway

20% of pediatric multiple trauma patients will require urgent invasive airway management

When do you want to perform an airway intervention in a pediatric trauma patient?

Hypoxemia

- Tachypnea
- Pallor
- Nasal flaring
- Retractions
- Grunting
- Agitation

- Cyanosis
- Altered LOC
- Fatigue
- Bradypnea, apnea
- Tachycardia
- Bradycardia

Respiratory Failure

- Marked tachypnea (early)
- Bradypnea, apnea (late)
- Tachycardia (early)
- Bradycardia (late)
- Increased, decreased, or no respiratory effort
- Cyanosis
- Poor air movement
- Decreased LOC
Airway Interventions

- Reposition airway
- Suction airway and belly
- High flow oxygen
- Simple Mask
  - Fits infants better upside down
- Bag/mask ventilation
  - With or without oral airway
- Intubation
- LMA
- Needle cricothyrotomy

What is your backup airway in a pediatric trauma patient?

LMA use in Pediatrics

- Used often in the OR as temporary airway
- Used in difficult airway protocol
- High success rate with proper training
- May be challenging to maintain placement in transport (easily replaced)
Needle Cricothyrotomy

- Surgical cricothyrotomy should not be attempted in children under 8-12 years of age
- Needle cricothyrotomy is the procedure of choice for children less than 10
- Temporary measure to oxygenate but not ventilate
- Can be used to oxygenate for up to 1 hour

Breathing

- If not intubated - assess adequacy of respirations
  - Look for signs of hypoxia/respiratory failure
- If intubated - assess ETT placement
  - EtCO2, breath sounds, chest rise
  - Place OG

Pediatric Trauma Contributing to Respiratory Distress

- Tension pneumothorax
- Open pneumothorax
- Hemothorax
- Flail chest
- Pulmonary contusions
- Diaphragmatic rupture
- Tracheobronchial injury
- Sternal fractures / Rib fractures

Circulation

- Heart rate
- Capillary refill
- Quality of pulses
- Level of consciousness
- Skin temperature
- Urine output (1-2 ml/kg/hr)
- Blood pressure
  - Up to 45% of circulating blood volume may be lost before a noticeable change in a child's blood pressure
What 3 things are the earliest indicators of changes in volume status of a pediatric patient?

- 1. Heart Rate
- 2. Capillary Refill
- 3. LOC

**Circulation**

- Total blood volume in a child = 80 ml/kg
- Most common cause of shock in pediatric trauma is hypovolemia
- Shock can occur with normal, increased, or decreased blood pressure

**Shock – 4 types**

- Hypovolemic
  - Hemorrhagic
- Distributive
  - Septic, neurogenic
- Cardiogenic
  - Myocarditis, arrhythmias, myocardial injury (trauma)
- Obstructive
  - Cardiac tamponade, tension pneumothorax

Treatment – prevention of end-organ injury and progression to cardiopulmonary failure and arrest!
What is the most effective way for a pediatric patient to increase their cardiac output?

**Contractility**

Newborns have limited ability to increase contractility

The ability to increase contractility goes up with age
- 30% of fetal myocardium contracts
- 60% of adult myocardium contracts

**Hypotension and Shock**

- Systolic blood pressure
  - Hypotension = SBP 70 + (2 x age in years)
- Compensated shock → hypotensive shock
- Hypotensive shock → cardiac arrest

**Treatment of Shock**

- High flow oxygen
- Vascular access (IV, IO)
- Aggressive fluid resuscitation
- Close monitoring and reassessment
- Pharmacologic support
Massive Transfusion

• 1:1:1 ratio of pRBC:FFP:PLT should be instituted in kids >30KG

• Those <30KG 30:20:20 ml/kg of pRBC:FFP:PLT

• Cryoprecipitate if continued hemorrhage after 1 round of each or fibrinogen levels < 1 - 1.5g/dl

MTP In The Literature

Chidester SJ et al.

• Prospective protocol to validate the 1:1:1 MTP
• No difference in mortality
• Those outside of the protocol had increased thromboembolic events.

Nosanov L et al.

• Retrospective review
• Did not find an increase in survival in children with higher FFP: pRBC or platelet: pRBC ratio.
• Found pediatric patients are more vulnerable to complications, such as metabolic derangements, related to blood transfusions.

Restrictive policy has also been adopted in the PICU

Hemoglobin of 7g/dL is considered a reasonable goal based on review of current literature.

Lacroix et al.

• No difference in MSOF or mortality using a restrictive approach in the PICU.

Palmieri TL et al.

• In the pediatric burn population – using a restrictive approach = no increase in mortality, length of stay or ventilator days.
• However those with a more liberal transfusion approach did have double the pulmonary complications.

Thromboelastography (TEG)

• Validated measure for fibrinolysis and assesses platelet function rather than total quantity.
• These results can be obtained much quicker than traditional coagulation studies.
• Calculates and reports the rate of clot formation, propagation and fibrinolysis in graphical form.
• Prospective data regarding the use of TEG in pediatric trauma is still lacking.
Rotational Thromboelastometry (ROTEM)
  • Modification of traditional TEG – investigates the interaction of clotting factors, their inhibitors, blood cells (PLT) during clotting and fibrinolysis
  • Detects hypo and hyperfunctional stages of the clotting process
  • POC testing becoming more common

TXA in Pediatric Trauma
  • Tranexamic Acid (TXA)
    – Antifibrinolytic that prevents the degradation of fibrin by inhibiting plasmin and plasminogen.
    – Use in adult trauma patients = reduction in mortality with early use in both civilian and military settings.
    – Has not been widely implemented in pediatric trauma.

TXA in Pediatric Trauma
  • American College of Surgeons - COT recommends: Thromboelastography should be available in Level I and II Trauma centers
  • Pediatric Trauma Society – June 2017
    • Viscoelastic monitoring (VEM) during active resuscitation is infrequently used by pediatric trauma providers even when available
    • Opportunity for quality improvement in pediatric trauma treatment

Eckert MJ et al. (2014)
  • Retrospective review of all pediatric trauma admissions
  • Used in approximately 10% of pediatric combat trauma patients:
    Findings:
    • Only independent predictors of TXA use = severe abdominal or extremity injury and base deficit of greater than 5.
    • Independently associated with decreased mortality.
    • No difference in thromboembolic complications or other cardiovascular events.
Pulseless Arrest

- Causes of traumatic arrest
  - Airway compromise
  - Tension pneumothorax
  - Hemorrhagic shock
  - Massive head injury

The most common immediate causes of pediatric cardiac arrest are respiratory failure and hypotension!

Pediatric Trauma Contributing to Circulatory Compromise

- Head injuries
- Facial/mandibular injuries
- Massive hemothorax
- Cardiac injury

Pediatric Trauma Contributing to Circulatory Compromise

- Traumatic aortic disruption
- Abdominal injuries
  - Liver and spleen most common
- Pelvic fractures
  - Uncommon unless hit by car
  - May be accompanied by bladder rupture
- Femur fractures

Disability

- AVPU
- Pediatric GCS commonly used
  - Score of 14-15 mild brain injury
  - Score of 9-13 moderate brain injury
  - Score of < 8 severe brain injury
- Pupil reaction / Symmetry
  - Unequal
  - Sluggish
- Movement of extremities
  - Indication of spinal cord injury
  - Look for posturing
Pediatric Trauma Score

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>&gt;20</td>
<td>10 to 20</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Airway</td>
<td>Normal</td>
<td>Maintained</td>
<td>Unmaintained</td>
</tr>
<tr>
<td>Systolic Blood Pressure (mm Hg)</td>
<td>&gt;90</td>
<td>50 to 90</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Central Nervous System</td>
<td>Awake</td>
<td>Obtunded</td>
<td>Coma/decerebrate</td>
</tr>
<tr>
<td>Open Wound</td>
<td>None</td>
<td>Minor</td>
<td>Major/penetrating</td>
</tr>
<tr>
<td>Skeletal Trauma</td>
<td>None</td>
<td>Closed fractures</td>
<td>Open, multiple fractures</td>
</tr>
</tbody>
</table>

Pediatric Trauma Score

- Inverse relationship to Injury Severity Score and mortality
- PTS <8 should ALL be triaged to appropriate peds trauma center
- 25% of all peds trauma victims have PTS >8
  - Highest potential for preventable mortality, morbidity and disability
  - Requiring most aggressive monitoring and observation

Head Injury

- More common injury in children
- Leading cause of mortality in peds trauma
- Occurs in up to 75% of multiple trauma victims
- More cerebral edema
- Fewer intracranial hematomas

So… normal CT does not mean normal brain or patient

- Size
  - Larger head
- Blood volume
  - Proportionately larger blood volume
  - Less myelinated
    - Predisposes it to shearing forces
  - DAI (Diffuse axional injury) grossly abnormal clinical findings without ICH
- Subarachnoid space smaller, less protection due to less bouyancy
- Musculature
  - Supportive muscles such as neck, back and abdomen are underdeveloped
What now??

Assume cervical injury
- < 8 years old, high injury suspected
- Occiput C1-C2 injuries
- Older kids will have more variable distribution
- SCIWORA
- Mortality rate of children with spinal fractures (54.4%) is significantly higher than adults (20.5%)

Markers for Mortality

Lethal Triad
- Hypothermia
- Acidosis
- Coagulopathy

All of these are present in trauma patients with significant bleeding

Skull Fractures

Skull fractures:
- Linear
  - Poor indicator of intracranial injury
  - Relatively common in < 1 year old
    - Relatively modest forces (should consider NAT though)
    - Occiput fx usually child struck repeatedly against object (NAT)
  - Epidural bleed if crosses middle meningeal artery
  - Overall good prognosis
Skull Fractures

Skull fractures:
- Depressed
  - Less frequent due to more force required
  - Suspect underlying injury due to force of bone pushing inward
  - Often require surgery due to underlying injury or for cosmetic regions

Epidural Hematomas

- Uncommon < 4 years old, then steadily increases
- Usually arterial bleeding
- Minor trauma may cause
- Lucid interval with subsequent decline
  - 1-4 hours later, pt c/o headache, progressive decline in MS
- Presentation
  - Bulging fontanel, unequal pupils, anemia
- Neurosurgical emergency

Subdural Hematomas

- Seen most in infants and adolescents
- Commonly associated with NAT
- Venous bleeding
- More force required
- May be chronic
- May or may not require surgical intervention
- Presentation
  - Non-specific, drowsiness, lethargy, irritability, retinal hemorrhages, seizures, tense/bulging fontanelle

Reassess and prevent

- Reassess A, B, C, D continually
- Protect the c-spine
- Secondary Brain Injury
  - Complex biochemical and cellular response to initial mechanical trauma
  - Can result in loss of tissue not initially damaged
- Physiologic effects include:
  - hypoxia, hypotension, ischemia, hypothermia
  
Prevent SBI by preventing/treating above conditions
Prevent hypo-perfusion

- Increased mortality with hypotension
  - Evidence based:
    - 509 kids (<17yo) with severe head injury (GCS<8) noted pts with hypotension had mortality rate 66%, whereas kids without hypotension had mortality rate of only 22%
  - Normal BP: 90 + (2 x child’s age)
  - Low end of normal is 70 + (2 x child’s age)
  - Cerebral perfusion pressure (CPP) \( CPP = MAP - ICP \)
    - Child > 50 mm HG
    - Adolescent > 60-70 mm HG

Prevent hypo-perfusion

- Don’t know ICP - IMPERATIVE to maintain the BP to keep CPP up
- CPP represents the pressure difference between the inflow (arterial) pressure and the outflow (venous) pressure across the cerebral vascular bed.
- Treat aggressively
  - LR
  - NS
- Continually reassess to avoid over or under fluid resuscitation

Head Injury Management

- Head midline & elevated 15-30 degrees
  - Treat shock first!!
- Control seizures- more common in peds
  - Benzodiazepines (hypotension)
  - Long-acting anticonvulsants (Fosphenytoin)
- Mannitol 0.25-1 gm/ kg or 3% Sodium Chloride 3-6mL/kg
- Sedation AND Paralysis
  - Assist with control of patient and ventilation
- Can help decrease O2 consumption and metabolism

To hyperventilate or not?

- Indicators
  - Evidence of herniation
    - Widening pulse pressure
    - Bradycardia
    - Irregular resp pattern
    - Pupil changes
  - Moderate hyperventilation
    - Normal tidal volume (approx 10 mL/ kg)
    - 1.25-1.5 times normal rate
    - Goal PaCO2 30-35 mmHG
      - High CO2 causes vasodilation which increases ICP
      - Dropping CO2 too low causes acidosis and vasoconstriction
**Pediatric Thoracic Trauma**

- Thoracic trauma is the second most deadly traumatic injury
- High incidence of pulmonary contusions and direct intrapulmonary hemorrhage
- Often with no overlying rib fractures

**Pneumothorax: Tension**

**Signs / Symptoms**
- Dyspnea
- Breath sounds on affected side
- PMI shift
- Hypotension
- Bradycardia (late)

MAY See:
- JVD
- Tracheal shift
- Chest wall movement

**Hemothorax**

- Seen less frequently than adults
- Poorly tolerated
- Treatment
  - Chest tube insertion

**Pediatric Abdominal Trauma**

- Incidence of abdominal injury is high due to:
  - Small pliable rib cage
  - Underdeveloped abdominal muscles
  - Lack of fat
  - Protruding abdomen
  - Proportionally larger solid organs
Abdominal Trauma

- Blunt trauma
  - 85% of peds traumatic injuries
  - MVC 50% of abdominal injuries
    - Others: pedestrian, bicycle, and sports
- Difficult to assess
  - Kids may deny pain out of fear
  - Air swallowing with crying may make abdominal exam difficult
- May be stable, then deteriorate rapidly
  - Serial exams should be conducted frequently

Presentation

- History
- External exam
  - “seatbelt sign”

Diagnostic Testing

- CT
- Ultrasound
- DPL (less frequent)

Diagnosis

- Serial exams
  - Every 4 hour H/H for splenic & liver injury
  - Most liver/splenic injuries PICU admits at CMH

Pediatric Abdominal Trauma

- Spleen & liver injuries most common
  - Currently, nonoperative management of isolated blunt hepatic and splenic injuries is considered the standard of care for hemodynamically stable children due to:
    - Post-splenectomy sepsis
    - Complications associated with non-therapeutic laparotomies
- Surgery:
  - unstable child who doesn’t respond to fluid resuscitation
  - hemorrhage
  - peritonitis

Pain Indicators

Behaviors:

- Facial grimace
- Guarding
- Lying still
- Resisting movement

Physiologic changes:

- ↑ HR
- ↑ Respiratory rate
- ↑ BP
- ↑ Perspiration
Pain Management Considerations

• Correct drug for desired effect
  – Sedation, analgesia, amnesia
• Appropriate dosing
  – Peds extremely weight dependent for dosing
• Adverse effects
  – All have them, some more fatal than others
• Monitoring
  – Must have intensive monitoring

Pain Management

• Start with low dose and increase as needed
• Dosing for light to no sedation in one, may cause deep sedation with possible airway compromise in another
• Increased metabolic rate in children can effect how they respond
• More sensitive to vasodilatory effects

Pain Management Pitfalls

• Kids have compensation abilities that lead to under-resuscitation which leads to rapid deterioration
• Assume every pediatric patient has multiple trauma
• Serial evaluations are crucial
References


References