The Pediatric Trauma Patient

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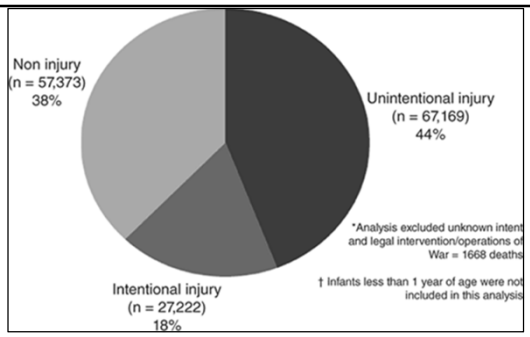
History

- Halifax 1917
- French cargo ship with explosives collided with Norwegian ship
  - Dr. William Ladd distressed by pediatric patients
    - Treated similarly to adults
      - Different anatomic, physiologic, surgical conditions
- 1970s
  - First pediatric shock trauma unit at Johns Hopkins
- 2010
  - Pediatric trauma centers: 43
    - 2015: 136[1]
  - Adult trauma centers (Level 1/2): 474

1. Pediatric Trauma Centers, A Report to Congressional Requesters. 2017

History

- One million children killed per year
  - 10,000,000 to 30,000,000 nonfatal injuries per year
  - US: 12,000 die, 1,000,000 nonfatal
- Injuries are leading cause of death age 1-19
- C. Everett Koop, former pediatric surgeon and US Surgeon General:
  - "If a disease were killing our children at the rate unintentional injuries are, the public would be outraged and demand that this killer be stopped."



Injury Patterns

- Infants
  - inflicted trauma, abusive
- Age 1-4
  - Fall
- Age 5-9
  - Pedestrian injuries
- Age 10-14
  - Motor vehicle

Location Matters

- 30% of children lack access to a pediatric trauma facility
  - Many go to those who have SOME training in pediatrics

"Children are not just little adults"

Initial Evaluation

- Initial workup the same: ABC
  - MCC Preventable prehospital cause of death:
    - Airway Obstruction
  - Prehospital cpr: poor prognosis
    - 25 children reviewed, blunt injury with prehospital cpr: no survival[1]
      - Majority from lethal CNS injury

1. Calkins CM, Bensard DD, Patrick DA, Karrer FM. A critical analysis of outcome for children sustaining cardiac arrest after blunt trauma. *J. Pediatr Surg*. 2002;37(2): 180-184.

Initial Evaluation

- Less than 40 kg
- Broselow Emergency Tape
  - Fluids
  - Drugs
  - Vital Signs
  - Equipment sizes
  - Beware:
    - May underestimate weight
      - By 2.6kg on average

Primary Survey: Airway

- Most inappropriate trauma care existing in ED phase:
  - Airway management[1,2]
    - Infants/young children: prominent occiput
    - Tilts head forward
    - Floppy epiglottis
    - Increased lymphoid tissue
- Upper airway obstruction common: especially in unconscious
  - Jaw thrust, chin lift

1. Esposito TJ, Sanddal ND, Dean JM, Hansen JD, Reynolds SA, Battan K. Analysis of preventable pediatric trauma deaths and inappropriate trauma care in Montana. *J Trauma*. 1999;47(2):243-251;discussion 51-3.
2. Sanddal TL, Esposito TJ, Whitney JR, et al. Analysis of preventable trauma deaths and opportunities for trauma care improvement in Utah. *J Trauma*. 2011;70(4):970-977.

Primary Survey: Airway

- Rapid desaturation
  - Increased metabolic rate
  - Increased oxygen consumption
  - Diminished functional residual capacity
- Treat quickly
  - Supplemental o2/bag mask ventilation
- Intubation indications: similar
- Adjuncts
  - Nasopharyngeal airways?
    - Nope

Primary Survey: Airway

- Direct laryngoscopy
  - Always assume neck injury
- Glidescope
  - Meta-analysis of 14 studies - improved glottic visualization but increased time[1]
  - Simulation of pediatric trauma - video laryngoscopy revealed lesser view with increased time
    - 21 seconds vs 7 sec[2]
  - So....direct laryngoscopy still considered standard, video with caution

1. Sun Y, Lu Y, Huang Y, Jiang H. Pediatric video laryngoscope versus direct laryngoscope: a meta-analysis of randomized controlled trials. *Paediatr Anaesth*. 2014;24(10):1056-1065.
2. Vlatten A, Litz S, MacManus B, Launcelott S, Soder C. A comparison of the GlideScope video laryngoscope and standard direct laryngoscopy in children with immobilized cervical spine. *Pediatr Emerg Care*. 2012;28(12): 1317-1320.

Primary Survey: Airway

- Narrowest point of airway
  - Cricoid cartilage (as compared to cords)
    - Choose the right tube!
      - Avoid laryngospasm
      - Avoid mainstem
        - Rule of thumb: three times the diameter of the tube should be the measurement at the lip
      - ETT diameter choice
        - Rule of the pinky fingernail
        - (Age in years + 16)/4
          - Rule of pinky fingernail better[1]

1. King BR, et al. Endotracheal tube selection in children: a comparison of four methods. Ann Emerg Med. 1993.

Primary survey: Airway

- Rapid Sequence Intubation
  - Feared?
    - Failure to intubate then failure to ventilate
  - Children: exaggerated vagal response to meds/manipulation (especially in TBI)
    - Premedications: lidocaine, atropine, fentanyl
  - Cricoid pressure
    - Minimal
  - Success measured as in adults
    - Capnography, symmetric breath sounds, chest rise

Primary survey: Airway

- Rescue maneuvers
  - Laryngeal mask airway (LMA)
    - Does not protect against aspiration
  - Cricothyroidotomy
  - Needle cricothyroidotomy
  - Translaryngeal jet ventilation
  - Literature limited in children

Primary Survey: Breathing

- Underdeveloped respiratory muscles, highly compliant chest, ribs less ossified
  - Increased risk for injury (minimal external signs)
  - Evidence that children with rib fx are more likely than adults to suffer brain injury, hemo/pneumothorax and spleen/liver injury
- Respiratory rate variations:
  a. Infant
     i. 60 times per minute
  b. Young children
     i. 40 times per minute
     ii. Use diaphragm - underdeveloped musculature - early fatigue
  c. Older children
     i. 20-30 times per minute
- TV goals: 6-8 ml/kg
  - Reduce barotrauma
- Need for chest tube?
  - Use Broselow tape

Primary survey: Breathing

- Gastric interference with respiratory mechanics
  - Tube early
    - no ngt if basilar skull fx/facial trauma

Primary Survey: Circulation

- Stroke volume generally fixed
  - Increase in cardiac output requires an increase in heart rate
  - SVR increased - shunting
- Exam
  - Skin color, hr, bp, peripheral pulses, level of consciousness
    - Delayed cap refill (greater than 2 seconds) in absence of hypothermia - bp may be maintained by increase in svr
      - child is hypovolemic
- Mortality
  - Increased in children suffering traumatic injury and hypotension
    - Gunst reported 2% mortality in hypotensive injured children[1]

1. Gunst MA, et al. Increased risk of death associated with hypotension is not altered by the presence of brain injury in pediatric trauma patients. Am J Surg. 2007.

Age group (years)	Weight range (kg)	Heart rate (beats/min)	Blood pressure (mm Hg)	Respiratory rate (breaths/min)	Urinary output (mL/(kg h))
Infant (0–1)	0–10	<160	>60	<60	2.0
Toddler (1–3)	10–14	<150	>70	<40	1.5
Preschool (3–5)	14–18	<140	>75	<35	1.0
School age (6–12)	18–36	<120	>80	<30	1.0
Adolescent (>12)	36–70	<100	>90	<30	0.5

Vascular Access

- Smaller veins, increased subcutaneous fat
- Goal:
  - 2 peripheral iv caths in upper extremities
    - See Broselow tape
    - Saphenous vein option
  - Failed? - three attempts or 90 seconds
    - IO access
      - Proximal tibia
      - Also distal tibia, proximal humerus and distal femur
      - Avoid in fractured extremity - extrav/compartment syndrome
  - Failed?
    - Central access

Primary Survey - Circulation

- Resuscitation
  - 20 ml/kg NS/LR
    - LR favored for risk of nonanion gap metabolic acidosis
    - Second bolus if warranted
  - Brain injury?
    - Hypertonic in kids too
  - Too much?
    - Greater than 150 ml/kg in first 24 hours?
      - Increase mortality
  - Too little?
    - No evidence to support permissive hypotension in children
- Hemorrhage control
  - TXA
    - Possible mortality benefit, no change in thromboembolic events[1]
    - 15 mg/kg over ten minutes (no more than 1 g) then 2 mg/kg/hr

1. Eckert, M. Wertin T, Tyner S, Nelson D, Izenberg S, Martin M. Tranexamic acid administration to pediatric trauma patients in a combat setting: the pediatric trauma and tranexamic acid study (PED-TRAX). 2014; 77(6): 852-858.

Primary Survey - Circulation

- Resuscitation
  - No response to crystalloid?
    - Give blood
  - FAST
  - Recommend 1:1:1 ratio
  - ED thoracotomy
    - Similar guidelines to adults
    - Similar outcomes in blunt
      - penetrating /witness cardiac arrest: better chance

Primary Survey: Disability

- Defined by:
  - Level of consciousness
  - Pupillary exam
  - Neuro exam
    - Can be more challenging in children
    - Variability in exam
      - Motor alone may identify those at risk from serious TBI[1]
        - Tx:
          - Similar
          - Etco2 25-30
          - 3% hypertonic bolus 1-6 ml/kg
          - IV mannitol 0.25-1 mg/kg

1. Acker SN. J Trauma Acute Care Surg. 2014

Primary Survey: Exposure

- More susceptible to hypothermia
  - Arrhythmias
  - Abnormal coag
  - Metabolic acidosis
- Trauma room greater than 80 degrees
- Hypothermic? 9.2 times more likely to die[1]

1. Sundberg J. Am J Emerg Med. 2011

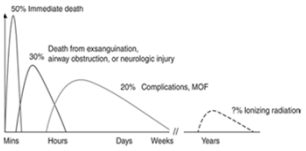
Secondary Assessment

- Chest and pelvis radiographs if indicated
  - Pelvis discouraged unless hypotensive
- Brief medical history/meds/immunizations
- Pain meds
- Abdominal trauma
  - Tenderness to palpation - 6 fold increase risk of abdominal injury (changes with declining gcs)
  - Bruising from seatbelt/handle bar - 232 times more likely to have injury[1]
- Fractures with minimal displacement
  - Greenstick fractures
  - Low threshold for imaging: hematoma, ttp, bruising
- FAST
  - 30-50% with solid organ injury will have negative FAST

1. Holmes JF, et al. Identification of children with intraabdominal injuries after blunt trauma. Ann Emerg Med. 2002.

Secondary Assessment

- Labs
  - Overall not that helpful
  - Metabolic abnormalities - lactate/deficit
- Imaging
  - Linear relationship between dose of radiation delivered during CT and relative risk of developing leukemia and brain cancer[1]
  - Don't use unless changes plan
    - Use basis of primary and sec survey

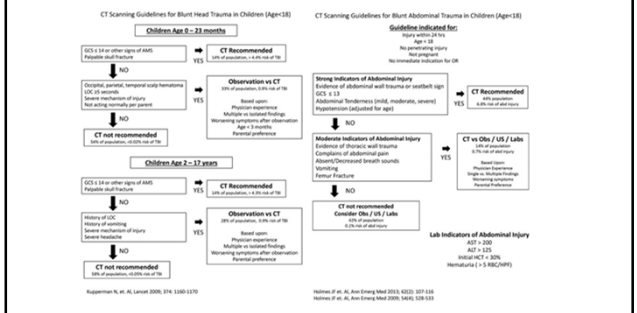


1. Pearce MS. Lancet. 2012.

Secondary Assessment

- When to CT head?
  - GCS less than 14
  - AMS
  - LOC greater than 5 seconds
  - Vomiting
  - Severe mechanism of injury
  - Skull fracture
  - PECARN Criteria
- Otherwise observe
- Negative predictive value 100%[1]

1. Kuppermann N. Lancet. 2009.



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Holmes JF et. Al, Ann Emerg Med 2013; 62(2): 107-116
Holmes JF et. Al, Ann Emerg Med 2009; 54(4): 528-533

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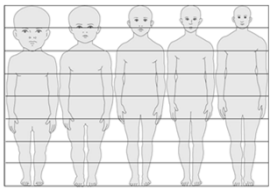
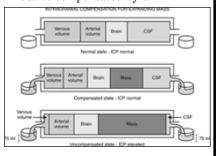
Neurologic Injury

- Head to body 1:4, to 1:7
- Suture closure: 3 years
- CSF volume decreased
- Brain water content increased
- Brain myelination incomplete until age 2



Neurologic Injury

- Monro-Kellie doctrine
  - Intracranial vault is incompressible and holds a fixed volume of brain, csf, and blood
    - Any increase in volume of one of the cranial constituents must be compensated by a decrease in volume of another
- Goals similar: icp less than 20, cpp greater than 40
- Level 2 guidelines by the The Brain Foundation
  - Hypertonic saline
  - Therapeutic hypothermia
- Level 3
  - Cpp greater than 40
  - ICP monitor for gcs less than 8
  - Avoid CO2 less than 30, adequate analgesia, sedation, paralytics
  - Prophylaxis with phenytoin



Neurologic Injury

- pCO2 35-40 optimal
  - Lower - decreased blood flow and increases secondary brain injury due to ischemia
- Serum osmolarity less than 360

Spine and Spinal Cord Injury

- Rare (less than 1% of all pediatric fractures)
  - C-spine susceptible to bony and ligamentous injury in kids
    - Neck poorly muscularized, ligaments lax and vertebral bodies are wedged anteriorly
- SCIWORA - spinal cord injury without radiologic abnormality
  - Transient neuro findings - but then worsen
    - MRI

Spine and spinal cord injury

- Absence of head injury/distracting injury
  - Clear clinically
- Lap belt sign
  - Increased risk lumbar spine fracture
    - Chance fracture - from flexion and distraction of upper lumbar vertebrae around the lap belt during rapid deceleration
      - Neurologic deficit risk high - remains in 10%
- Tx
  - Avoid secondary injury
    - Spine immobilization
    - Resuscitation/perfusion
    - Steroids - nope
- Overall better prognosis than adults

Thoracic Injuries

- 80% from blunt
- Chest wall more compliant
  - Less muscle, ribs more easily deformed
    - Greater transfer of energy to organs with force
    - Rib fractures uncommon
      - Underlying lung, liver, spleen more common
- Imaging
  - CXR usually suffices - ct rarely changes management
    - Risk of cancer higher than identifying aortic injury
    - High risk management, abnormal films, abnormal physical findings
  - E-FAST helpful

Thoracic Injuries

- Pulmonary contusion[1]
  - Most recover quickly
    - pneumonia/ards complication
- Pneumothorax
  - Seen on ct but not cxr - monitor
  - Tension
    - Tx like adult - needle thoracostomy/chest tube
- Hemothorax
  - Small chest tube as effective as large
    - Possible decreased risk empyema
  - OR: greater than 15 ml/kg or greater 2-3 ml/kg/hr for more than 3 hours

1. Wyke J, et al. Lung contusion in children – early computed tomography versus radiography. Pediatr Crit Care Med. 2009.

Thoracic Injuries

- Mediastinum
  - No differences
  - Endovascular stenting/thoracotomies/etc

Traumatic Asphyxia

- Injury caused by compression of chest and upper abdomen
  - Marked elevation of pressure in svc and feeding branches
  - Swelling of face and petechial hemorrhages in skin above nipple line/conjunctivae
  - Occasional resp distress
- Most recover with elevation upper body and oxygen by mask or nasal cannula

Commotio Cordis

- Direct blow to anterior chest
  - Sudden cardiac collapse from v-fib
- Children
  - Increased risk due to thin, pliable anterior chest
  - Male, age 14 years, usually during sports
- Fatal in more than 50%

Abdominal Injuries

- Anatomic variations
  - Thin abdominal wall
  - Lack of protection from ribs: liver/spleen
- Laparotomy
  - Generally based off of clinical exam, not imaging
    - Seat belt sign on lower abdomen
      - Increased risk of injury - bowel/pancreas/spine
  - Diagnostic delay bowel injury
    - Not same adverse result as in adults
- FAST

Liver/spleen

- Packing/embolization similar to adults
- Spleen
  - Children usually fail non-op within the first 24 hours

Pancreas

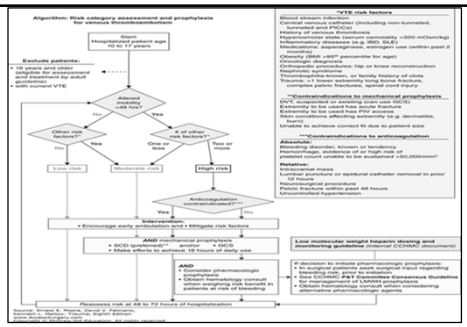
- Bike handlebar, etc that compresses pancreas against spine
- Difficult to dx
  - Amylase low sensitivity/specificity
    - Better to watch trend
- Tx
  - Complete ductal transection
    - Multicenter study - distal pancreatectomy with improved outcome

Vascular Injury

- Uncommon in children
  - Supracondylar fracture mec limb ischemia
    - Complication rate up to 24%
      - Early anatomical reduction of the fracture, fixation
- More rapid collateralization
  - Anticoag/observation if limb not threatened

Venous Thromboembolism

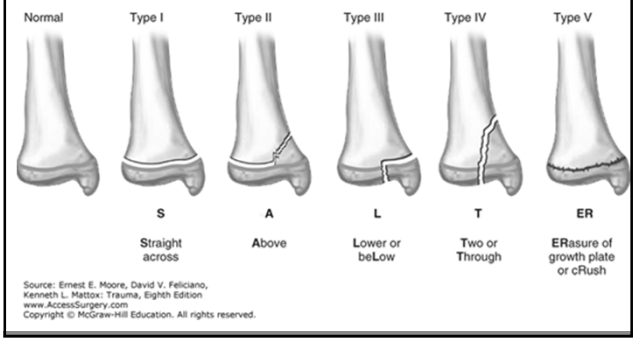
- Low incidence of dvt compared to adults
  - Decreased capacity to generate thrombin, increased inhibition of thrombin, enhanced antithrombotic potential by the vessel wall
  - 5/10,000 hospital admission
  - Teenage girls - double the rate (estrogen)
- Where
  - 67% at site of CVC
- Risk factors
  - High risk: greater than 13y, four or more of:
    - Projected immobility greater than 5 days, GCS less than 9, presence of CVC, spinal cord injury, chronic inflammatory state, h/o previous clot, known thrombophilia, current malignancy
      - LMWH bid



1. CincinnatiChildrens.org. Best Evidence Statement, 2014

Musculoskeletal

- Most common fracture:femur
  - Tib +/- fib, humerus, radius/ulna, vertebral
- Less than 18 months of age with lower extremity fracture
  - 41/55 were attributed to abuse in a level 1 pediatric trauma center
- Anatomy
  - Pediatric bone less dense, more porous (greater energy absorption, decreases propagation of fracture lines - why you have less comminuted fx)
  - Periosteum thick - minimizes fracture displacement
    - Greenstick fracture - bone is fractured with only partial disruption of the periosteum resulting in angulating without displacement
    - Torus/buckle fracture - compression of bone
  - Physis/growth plate - provides longitudinal growth
    - Weakest portion of bone



Musculoskeletal

- Physis
  - Complete injury - arrest of growth
    - Especially 3-4
- Radiographs
  - Include joint above and below
- Healing
  - More rapid in children
    - Stable union within 1 week in a neonate
      - Thick periosteum stabilizes and is major contributor to new bone formation

Child Abuse

- 1962 Article: Battered Child Syndrome
  - Now mandatory that physicians report instances of child abuse
- 12/1000 children
  - 72% from single parent households
  - 37% mothers age less than 21 years
  - 26% history of prior child welfare involvement in the family
- Exam
  - Multicolored bruises
  - Old fractures
  - Retinal hemorrhage

In Summary:

- As a parent:
  - Live closer to a trauma center
  - Don't let my child climb higher than 3 feet, car seats, helmets
  - Don't let them run in the street
- As a caretaker:
  - Understand they are different than adults
  - AIRWAY!!!!!!!
  - Think ahead - have charts, tape handy for reference
  - Stabilize, ship out

Resources

1. Moore, E., Feliciano, D. and Mattox, K. Trauma. 8th Edition. 2017.
2. Calkins CM, Bensard DD, Patrick DA, Karrer FM. A critical analysis of outcome for children sustaining cardiac arrest after blunt trauma. *J. Pediatr Surg.* 2002;37(2): 180-184.
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