PEDIATRIC TRAUMA

Surgical Specialty:	Trauma Surgery
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Background:

- General Considerations[1]
  - Trauma is the leading cause of morbidity and mortality in children in the United States.
  - Trauma is attributed to 65% of all-cause mortality in children >1 year old.
  - Blunt trauma is the most common, with penetrating injuries occurring only 10-20% of the time.
  - Diagnostic examination under sedation or anesthesia is often required before definitive care and requires flexibility and vigilance.[1]
- Patient Considerations [2-3]
  - Age and gender are crucial factors influencing the pattern of injury
    - Infants and toddlers – falls are the most common.
    - Older children and adolescents – bicycle-related injury, with or without concurrent motor vehicle injury.
  - The central nervous system (CNS) is the most injured body system.
    - Less than 2 years old – physical abuse is the most common cause of serious head injury.
    - 'Shaken baby' should be suspected with retinal hemorrhage and the diagnosis offers few external signs.
    - Greater than 3 years old – falls, bicycle, motor vehicle, and pedestrian accidents are the most common cause of CNS injury.
  - Traumatic Brain Injury (TBI) occurs in 80% of pediatric trauma-related CNS injuries.
- Associated Comorbidities/Syndromes
  - No specific associated comorbidities/syndromes.

Anesthetic Planning:

- Initial Assessment and Resuscitation (often occurs in trauma bay or ED)
  - Primary Survey is the initial phase and should address life-threatening injuries.
  - "**ABCDE**" - Airway, Breathing, Circulation, Disability and Exposure
    - **A**irway – 100% oxygen, rapid sequence induction, plan for increased ICP.
    - **B**reathing/**C**irculation - control ventilation, consider shock, and obtain vascular access.
      - Consider intra-osseous access if quickly unable to obtain peripheral or central access.

        - **D**isability – neurologic status with Glasgow Coma Scale (GCS), which is modified in children. GCS <8 is considered a severe neurologic injury.
        - **E**xposure of the child for a complete examination
    - Secondary survey – begins after the primary survey and identifies injuries missed, return to primary survey if the patient becomes unstable.
        - Diagnostic testing – CT (brain, neck, chest, abdomen, pelvis), chest x-ray, abdominal ultrasound, blood cell count, electrolytes, and blood crossmatching.
    - Consider obtaining an "**AMPLE**" history if a caregiver or patient is able to during the secondary survey.
        - **A**llergies, **M**edications, **P**ast illness, **L**ast meal, **E**vents preceding injury.
- Specific or Unique Room Set-up Requirements
    - Airway
        - Rapid sequence induction. Full stomach precautions.
        - Plan for a difficult airway. An airway exam is often not possible.
        - Airway equipment should include:
            - Multiple age-appropriate ETT with stylets and supra-glottic airways as a backup.
            - Video-laryngoscope with multiple blades (including hyper-acute angle).
            - Flexible intubating scope – confirm that it passes through the chosen ETT prior to use.
            - Wide bore suction catheter and Yankauer with functioning suction.
            - Consider surgeons on standby for rigid bronchoscopy and extra corporeal membrane oxygenator (ECMO) (included in the pediatric difficult airway algorithm).
    - Intravenous vascular access / Special devices
        - Two age-appropriate large bore cannulas.
        - Standby level 1 Belmont™ or Rapid Infuser System (RIS)™ with warmer.
        - Central vein cannulation (femoral preferred), arterial catheter insertion.
        - Echocardiography is gaining popularity and is recommended.
    - Drugs/Infusions
        - Induction agents – titrate all doses based on sedation level and existing meds. Use caution if hemodynamically unstable.
            - Propofol (1-3 mg/kg)
            - Ketamine (IV 1-3 mg/kg, IM 4-8 mg/kg)
            - Etomidate (0.2-0.6 mg/kg)
            - Fentanyl (1-3 mcg/kg)
                - Often an adjunct, consider solo if hemodynamically unstable.
        - Paralytics
            - Succinylcholine (IV 1-2 mg/kg, IM 2-4 mg/kg)
                - Avoid in patients with hyperkalemia, physical deconditioning, burn, crush, or severe muscle injury patients. If in doubt, avoid use.
            - Rocuronium (0.6-1.2 mg/kg)
        - Emergency (PALS/resuscitation)
            - Epinephrine (IV 1-10 mcg/kg, Infusion 0.02-1 mcg/kg/min)
                - Consider multiple bolus concentrations to assist with rapid dosing – 1, 10, and 100 mcg/ml syringes.
            - Atropine (IV 10-20 mcg/kg, IM 20 mcg/kg)
            - Calcium chloride (5-10 mg/kg)

        - Dopamine (0.5-20 mcg/kg/min)
    - Steroids
        - Hydrocortisone (1-2 mg/kg)
            - Consider stress dose if severe hypotension.
        - Discuss dosing if neurosurgery.
    - PONV prophylaxis
        - Often not required unless considering extubation.
        - Ondansetron (0.1-0.15mg/kg) -max 8 mg.
    - Emergence delirium prophylaxis
        - Not indicated
- Monitors
    - Standard American Society of Anesthesiologists monitors
    - Central (Femoral preferred) and arterial line are recommended.
- Blood Availability
    - Packed red blood cells (PRBCs,) fresh frozen plasma (FFP), and platelets in the room
    - Typically given in a 1:1:1 ratio of 10 ml/kg.
    - Blood loss is often hard to estimate. Give blood products until hemodynamically stable. Consider sending off an arterial blood gas (ABG) and thromboelastography (TEG).
- PICU Bed Availability
    - Usually required, often multiple services and organ systems are involved.
- Other Indicated Resources
    - ECMO standby.
    - Consider transplant services.
    - Update family often.
    - In extreme situations, consider bringing family into the operating room (OR).

Intraoperative Considerations:

- General
    - Warm the OR. Use convective warmers and radiant lamps.
    - Intraoperative management should be dictated by patient status.
    - For the critically ill, emergently transferred child to the OR, surgery should proceed following a rapid sequence induction (RSI), vascular access, a blood pressure cuff, pulse oximeter, expired carbon dioxide, and electrocardiogram.
    - As conditions permit, consider adding larger bore vascular access, and central and arterial access.
- Induction
    - Pre-oxygenate with 100% oxygen.
    - Recall is more common in trauma cases. Give step-wise sedation as hemodynamic status allows. IV midazolam is strongly recommended.
    - Induction of anesthesia should be tailored for each patient, avoiding hypoxia and hypercapnia.
    - All trauma patients have an increased aspiration risk given the autonomic-induced delayed gastric emptying.
    - Use a RSI in all trauma patients, with a possible exception for a difficult airway.
        - Immediate large-bore Yankauer suction must be available.

        - Suction-Assisted Laryngoscopy Airway Decontamination (SALAD) offers simultaneous suctioning during airway intubation to decrease secretions and blood present during intubation.[4]
        - Novel techniques combining the suction catheter with the video-laryngoscope blades have been recommended for hematemesis and airway trauma when the oral cavity can accommodate.
- Positioning
    - Cervical spine injury is common, leave the cervical collar in place if possible.
    - Co-existing injuries are common, pad and stabilize where possible to avoid further injury.
- Maintenance
    - Where hemodynamics allow, Sevoflurane plus supplemental midazolam and fentanyl boluses.
        - Routine rocuronium dosing.
        - Nitrous oxide should be avoided in trauma, given its risk of gas trapping in enclosed air spaces in the abdomen, thorax, and cranium.
- Hemodynamic/Physiologic Goals
    - If neurosurgery, discuss physiologic goals for possibly elevated intracranial pressure
    - Avoid hypotension with bolus and infusion vasopressors (epinephrine preferred)
    - Treat bleeding with blood products
    - Consider recall
    - Maintain normothermia
    - Good communication with the surgeons
- Surgical Considerations (such as neuromonitoring, muscle relaxation, anticipated blood loss)
    - Neuromonitoring is not common.
    - Muscle relaxation is preferred during the case.
    - Anticipate blood loss and difficulty measuring estimated blood loss, and have balanced blood products immediately available.
    - Consider lung-protective ventilator strategies.
        - Avoiding baro/volutrauma by using tidal volumes of 6mL/kg
        - Increase positive end-expiratory pressure, if necessary to optimize oxygenation
- Emergence/Disposition
    - Trauma patients often remain intubated and are transferred directly to the Pediatric Intensive Care Unit (ICU).
- Post-op Care
    - ICU level of care to monitor for bleeding, coagulopathy, and other organ injury.
    - Adequate pain control and sedation are critical.

Case-Specific Complications/Pitfalls:

- Primary damage control and massive transfusion protocols have improved outcomes in pediatric trauma.
    - There is no consensus on the definition of massive transfusion in children.
    - The table below may be used for guidance; however, ongoing losses with transfusion of more than 10% total blood volume per hour may also be considered as a massive transfusion intra-operatively.

Blood volumes and massive transfusion definitions by age group.

Age group	Estimated blood volume	Massive transfusion
Premature neonate	100 mL/kg	50 mL/kg over 12 h 100 mL/kg over 24 h
Term neonate	90 mL/kg	45 mL/kg over 12 h 90 mL/kg over 24 h
Infants	80 mL/kg	40 mL/kg over 12 h 80 mL/kg over 24 h
Older children	70–80 mL/kg	35–40 mL/kg over 12 h 70–80 mL/kg over 24 h

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- Assume c-spine injury in pediatric trauma and leave the c-collar in place. Internal jugular vein central access should be avoided due to possible neck rotation.
- Shock is most commonly hypovolemic in children and early interventions are critical.
    - Tachycardia has many other causes to consider.
    - Volume depletion is often underestimated. Hypotension and decreased urine output often do not occur until >30% blood loss.
- Early resuscitation goals are
    - Normalization of baseline vital signs and age-appropriate blood pressure & heart rate.
    - Adequate urine output (1–2 mL/kg).
    - Initial fluid resuscitation with a warm isotonic solution – lactated Ringer's or Plasmalyte at 20-30 ml/kg.
    - Consider RBCs 10 mL/kg if there is a poor response to the initial fluid bolus.
- If an initial crystalloid bolus (total of 30mL/kg) fails to achieve the physiological targets, then blood products should be transfused guided by point-of-care testing (POC), if available. Consider whole blood (20 mL/kg), if possible.
- Coagulopathy is more common in the pediatric population. [2-3]
    - Beyond PRBCs transfusion of 10-20 mL/kg, coagulopathy occurs due to dilution of clotting factors.
    - Massive bleeding, transfuse at a balanced component ratio of 1:1:1 (PRBCs: FFP: Platelets).
        - **PRBC** 10-15 mL/kg should raise Hgb 2-3 g/dL, Hct by 6-9%
        - **FFP** 10-15 mL/kg should raise factor levels 15-20%
        - **Platelets** 10-15 mL/kg should raise platelet count by 30-50,000
- TEG has been widely accepted in adult patients but has not been adequately studied in children, transfusion goals should be based on the clinical picture and available POC tests.[6]

References

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