**Disclosures**

- No persons who have contributed to this presentation have any financial disclosures
- No off label or investigational use will be discussed

**Learning Objectives**

- Discuss primary and secondary trauma survey
- Discuss anatomy
- Discuss mechanisms and patterns of injury
- Discuss pharmacological management of traumatic injuries
- Discuss outcomes for pediatric trauma

**History and Physical**

- Chief Complaint: 21 year old Male involved in MVC with fatalities
- HPI: Reportedly unrestrained passenger in backseat of car
  - Found underneath two front seats unresponsive
  - Agonal respirations and intubated by EMS at the scene after extrication
  - One fatality at scene; three other critically ill patients brought to hospital
  - Transported via EMS after intubation to Trauma Bay
  - Longboard and cervical collar in place
  - PIV x 2 inserted in field
  - NS bolus 500 mL
  - Time of notification for Trauma Code: 0545

**Mechanism of Injury**

- Mechanism of injury (MOI): refers to the method or sequence of events by which damage to skin, muscles, organs and bones happens.
- The MOI is used to estimate the forces involved in trauma and, thus, the potential severity for wounding, fractures, and internal organ damage that a patient may suffer as a result of the injury.
- Healthcare providers use mechanism of injury to help determine how likely it is that a serious injury has occurred.

**CDC Trauma Triage Anatomic & Physiologic Criteria**

- Examined the MOI that was associated with the admission and determined whether or not the patient needed the resources of the Level One Trauma center.
- Trauma center need defined as: 1) Died, 2) ICU admission, and/or 3) Non-orthopedic surgery within 24 hours of admission.
- Conclusion: 1) Death of an occupant in the vehicle; 2) Fall greater than 20 feet; and 3) Extrication time > 20 minutes were good predictors of trauma center need when a patient did not meet the anatomic or physiologic conditions. Intrusion, ejection, and vehicle deformity were moderate predictors.
CDC 2011 Guidelines for the Field Triage of Patients

Step One: Physiologic Criteria
- Glasgow Coma Score ≤13
- Systolic Blood Pressure <90 mmHg
- Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support

Step Two: Anatomic Criteria
- All penetrating injuries to head, neck, torso, and extremities proximal to elbow or knee
- Chest wall instability or deformity (e.g., flail chest)
- Amputation proximal to wrist or ankle
- Two or more proximal long-bone fractures (i.e., femur and humerus)
- Crushed, degloved, mangled, or pulseless extremity
- Pelvic fractures
- Open or depressed skull fracture
- Paralysis

Step Three: Mechanism of Injury Criteria
- Adult: falls >20 feet
- Children: falls >10 feet
- Intrusion, including roof: >12 inches occupant site; >18 inches any site
- Ejection (partial or complete) from automobile
- Death in same passenger compartment
- Vehicle telemetry data consistent with a high risk of injury
- Auto vs. pedestrian/bicyclist thrown, run over, or with significant (>20 mph) impact
- Motorcycle crash >20 mph

Step Four: Special Considerations
- Age >55 years
- Systolic blood pressure <110 in persons aged >65 years
- Falls in older adults (e.g., ground-level falls)
- Pediatric trauma transport
- Anticoagulant use and bleeding disorders
- Burns
- Pregnancy >20 weeks
- Emergency medical services provider judgment

Outcome Variables
- Clinical outcomes
  - Injury severity score >15†
  - Abbreviated Injury Score ≥3
  - Death prior to hospital discharge
- Trauma center need
  - Blood product transfusion
  - Interventional radiology procedure
  - Major nonorthopedic surgery within 24 hours
  - Admission to intensive care unit

* Variables and cut-off values should be used at a minimum in evaluation of field triage guidelines. The criteria preceding the criterion of study should be included in the analysis to control for those patients captured by the previous step(s).
† Minimum outcome variable for inclusion.

Physical Principles and Physics

- Newton’s First Law of Motion
  - A body in motion remains in motion until acted upon by an outside force

- Kinetic Energy
  - the movement energy of an object which can be transferred between objects and transformed into other kinds of energy

- Law of Conservation of Energy
  - Energy cannot be destroyed but may be transferred to another object

Kinetic Energy

- Energy of motion: When two objects collide, each of them has an amount of energy.
- K.E. = 1/2 mass x velocity²
- Major factor = Velocity
- “Speed Kills”

Newton’s First Law of Motion

- Body in motion stays in motion unless acted on by outside force
- Body at rest stays at rest unless acted on by outside force

Law of Conservation of Energy

- Energy cannot be created or destroyed
- Only changed from one form to another

Energy Principles Conclusions

- When moving body is acted on by an outside force and changes its motion, kinetic energy must change to some other form of energy.
- If the moving body is a human and the energy transfer occurs too rapidly = Trauma
Motor Vehicle Crashes

- Front impact
- Back impact
- Side impact (T-boned)
- Combined impact
- Vehicle may be turned over
- Patient may be ejected from vehicle

The amount of energy and the direction of impact are major factors that determine the outcome of a crash.

Side Impact

- Region of the body which is closest to the side of impact will be injured directly, while those away from the impact may hit the other side of the vehicle.
- Severe brain and thoracic injuries and mortality occur more frequently.
- The nearer the occupant is to side of the impact, the more serious his/her thoracic or abdominal injury will be.

MOI and Trauma Services

- The only MOI criteria with any degree of validity:
  - ejection from a vehicle
  - prolonged extrication time
- Several studies - "ejection from a vehicle" has positive predictive value for severe injury.
- Pediatric studies have also demonstrated that "ejection from a vehicle" is a useful predictor of severe injury and the need for a trauma.

History and Physical

- Weight: 154 lbs/70 Kg
- Height: 5 feet 8 inches
- Medications: Unknown
- Allergies: Unknown
- PMHx: Unknown
- PSHx: Unknown
- Family Hx: Unknown
- Social Hx: Unknown
- ROS: Unable to be obtained
- Last Meal: Unknown
- Time of Injury: Unknown
- Mechanism of Injury: MVC, unrestrained backseat passenger whose vehicle was T-boned by another vehicle; + fatalities at the scene in both vehicles; speed unknown, + airbag deployment

H+P: Trauma Resuscitation

- Exam: Time 0605
- Vital Signs: HR 134, BP 159/110, RR-assisted, T 98 F, O2 Sat 99%
  - Airway/Breathing: trachea midline; respirations assisted; lungs sounds normal bilaterally; chest wall integrity normal
  - Circulation: Pulses all 2+; Bleeding-No; Perfusion-pink, warm, CRT <3 secs
  - Disability: gross motor function-None for left/right upper and lower ext; no raccoon's eyes/ Battle sign/hematympanum; GCS=3T
  - Abdomen/Genitourinary: abd soft; Pelvis -stable; absent blood at ureteral meatus
  - Posterior Exam: spine precautions maintained; rectal tone-NL; no gross rectal blood

H+P: Trauma Resuscitation

- Procedures/Interventions:
  - 0605: FAST=Positive RUQ
  - 0608: Trauma Labs obtained
Question
You are the provider in the ER. What laboratory studies would you order?
A. CBC
B. Comprehensive electrolytes
C. Coagulation Panel (PT/INR/PTT)
D. Urinalysis
E. All of the above

Trauma Evaluation Labs:
Blunt Abdominal Trauma
- Stable
  - CBC
  - Type and cross for PRBCs
  - Rapid blood glucose
  - Liver enzymes
  - Serum amylase and lipase
- Unstable
  - CBC with differential
  - Coagulation Profile (PT/INR/PTT)
  - Serum Chemistries with LFTs
  - ABG/VBG
  - Blood ethanol level and urine screen for drugs of abuse
  - Urine pregnancy test (postmenarchal females)

H+P: Trauma Resuscitation
- Procedures/Interventions:
  - 0605: FAST=Positive RUQ
  - 0608: Trauma Labs obtained
  - 0615: Foley – 16 Fr inserted, amber urine
    - Transported to Radiology
      - CXR, CT: Head, Neck, Chest/Abd/Pelvis, C-spine, T-spine, L-spine

Blunt Abdominal Trauma
- Blunt abdominal trauma occurs in 10%-15% of injured children
- Liver and Spleen- most common potentially life-threatening intraabdominal injuries in children
- Pancreatic injury- less common; may result in peritonitis or pseudocyst if large duct is transected
- Prognosis: for all 3 types of injuries depends upon associated injuries, esp. brain and thorax

Abdominal Anatomy
- The liver, spleen, and pancreas lie in the upper abdomen partly protected by the ribs.
- Children have relatively larger viscera, less overlying fat, and weaker abdominal musculature.
- In children, almost all injuries to the liver, spleen, and pancreas are caused by blunt force.
- The mechanism can be a direct blow to the epigastrium with deformation of the abdominal wall, avulsion of the blood supply by rapid deceleration, puncture by a fractured rib, or crushing against the vertebral column.

Abdominal Anatomy
- The liver and spleen are highly vascular, fatal blood loss either from the parenchyma or the arteries and veins that supply them.
- The spleen can be removed completely to stop bleeding when all other approaches fail.
- The liver has a dual blood supply via the hepatic arteries and the portal vein. Blood flows from the posterior-superior surface of the liver into the IVC via the hepatic veins. Injuries to these vessels may lead to rapid exsanguination. The liver is relatively large and has less fibrous stroma than in adults.
- Parenchyma of the pancreas is not as vascular as the liver and spleen
- Pancreatic trauma- release of pancreatic juice, resulting in local peritoneal and retroperitoneal inflammation.
Evaluation of Blunt Abdominal Trauma

• Secondary Survey: evaluation for blunt abdominal injuries

• The diagnosis of injuries to the liver, spleen, and pancreas:
  • history and physical examination
  • confirmed by diagnostic imaging

• These injuries cause harm through two basic mechanisms:
  • Bleeding from the parenchyma of the spleen and liver or the major blood vessels that supply these organs
  • Peritonitis from the release of pancreatic juice

Delayed Presentation

• Delayed PE Findings:
  • delayed presentation of splenic injury (hemorrhage from the ruptured spleen more than 48 hours after trauma) can present with left subcostal pain; left shoulder pain; abdominal distension, rigidity, or rebound tenderness; fullness in the left upper quadrant; or anemia.
  • delayed presentation of pancreatic trauma may have findings suggestive of pancreatic pseudocyst, including epigastric pain, palpable abdominal mass, peritoneal findings, and elevated lipase or amylase

Abdominal Trauma

• PE Findings
  • Abdominal tenderness, specific patterns may be associated with the injured organ:
    • Right upper quadrant tenderness or superior midline abdominal tenderness – Liver or pancreas injury
    • Left upper quadrant tenderness – Splenic injury
    • Epigastric tenderness – Pancreas injury
  • Abdominal wall ecchymosis or abrasions ("seat belt sign" or midline abdominal bruise from a bicycle handlebar)
  • Abdominal distension

Imaging

• Focused Assessment with Sonography for Trauma (FAST): rapid ultrasound exam of four abdominal locations
  • Right upper quadrant, left upper quadrant, subxiphoid region, pelvis
  • Primary utility: unstable trauma patient; detection of hemopericardium and/or intraperitoneal fluid secondary to intraabdominal injury
  • Used with unstable trauma patients
  • Supplanted the DPL procedure
  • FAST with blunt injury may warrant operative intervention in lieu of CT Abd/Pelvis

Imaging Results

• Head CT: No acute intracranial findings identified
• CT Cervical Spine: No gross cervical spine abnormality; R PTX
• CT Lumbar Spine: No evidence of acute fx or traumatic subluxation
• CT Thoracic Spine: No evidence of acute fx or traumatic subluxation
• CXR: ETT good position; Right PTX (20%)
Stabilization of Blunt Abdominal Trauma

- ATLS Protocol for airway, breathing, circulation
- Pediatric Trauma Center- most appropriate environment
- Classification Systems: liver, spleen, or pancreas injury are typically based upon CT images
- Management:
  - Most are non-operative
  - decision to operate is based upon hemodynamic stability, not CT findings
  - Hemodynamically unstable: do not improve with fluid resuscitation ➞ emergent exploratory laparotomy

AAST Liver Injury Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Hematoma: subcapsular, &lt;10% surface area</td>
</tr>
<tr>
<td></td>
<td>Laceration: capsular tear, &lt;1 cm parenchymal depth</td>
</tr>
<tr>
<td>II</td>
<td>Hematoma: subcapsular, 10-50% surface area</td>
</tr>
<tr>
<td></td>
<td>Hematoma: intraparenchymal &lt;10 cm diameter</td>
</tr>
<tr>
<td></td>
<td>Laceration: capsular tear 1-3 cm parenchymal depth, &lt;10 cm length</td>
</tr>
<tr>
<td>III</td>
<td>Hematoma: subcapsular, &gt;50% surface area or ruptured subcapsular or parenchymal hematoma</td>
</tr>
<tr>
<td></td>
<td>Hematoma: intraparenchymal &gt;10 cm or expanding</td>
</tr>
<tr>
<td></td>
<td>Laceration: capsular tear &gt;3 cm parenchymal depth</td>
</tr>
<tr>
<td>IV</td>
<td>Laceration: parenchymal disruption involving &gt;25% hepatic lobe or segments</td>
</tr>
<tr>
<td></td>
<td>Vascular: juxtahepatic venous injuries (retrohepatic vena cava / central major hepatic veins)</td>
</tr>
<tr>
<td>V</td>
<td>Laceration: parenchymal disruption involving 1-3 Couinaud segments</td>
</tr>
<tr>
<td>V</td>
<td>Vascular: hepatic avulsion</td>
</tr>
<tr>
<td>VI</td>
<td>Vascular: hepatic avulsion</td>
</tr>
<tr>
<td>VI</td>
<td>N.b. advance one grade for multiple injuries up to grade III</td>
</tr>
</tbody>
</table>

Liver Laceration – Grade V

Liver Laceration – Grade V
Definitive Management- Liver

- Non-operative Management
- Angiographic Embolization
- Laparotomy
- Damage Control Surgery

H+P: Trauma Resuscitation

- Procedures/Interventions:
  - 0605: FAST=Positive RUQ
  - 0608: Trauma Labs obtained
  - 0615: Foley – 16 Fr inserted, amber urine
    - Transported to Radiology
    - CXR, CT- Head, neck, chest/Abd/Pelvis, T-spine, L-spine
  - 0630: Return to Trauma Bay
  - 0640: Right Chest Tube 16 Fr
  - 0645: PRBC 300mL; Right CT output=200mL, U/O= 50 mL; NE gtt started
  - 0650: Right Femoral CVL
  - 0700: OR

Question

What is the leading cause of preventable traumatic death in children greater than 1 year of age?

A. Head
B. Homicide
C. Suicide
D. Hemorrhage
E. Non-accidental

Hemorrhage

- Hemorrhage is the most common cause of medically preventable death for trauma patients
- Typically occurs within 6 hours from the initiation of bleeding
- Damage Control Resuscitation (DCR): current treatment approach for traumatic hemorrhagic shock
- Goal: prevent death from hemorrhage by rapid identification and control of shock and coagulopathy

Question

What is the preferred treatment strategy for Damage Control Resuscitation for traumatic hemorrhagic shock?

A. Whole Blood Transfusion
B. Ratio of 1 PRBC: 1 FFP: 1 Plt
C. Ratio of 2 PRBC: 1 FFP: 1 Plt
D. Ratio of 3 PRBC: 1 FFP: 1 Plt
E. Physician Discretion

Lethal Triad of Trauma

- Triad: worsening cycle of coagulopathy, hypothermia and acidosis
- Hypothermia-result of shock, exposure and large volume room temperature resuscitation fluids results in platelet activation and adhesion
- Hemodilution-results from infusion of crystalloid and/or PRBCs without sufficient co-infusion of FFP and Platelets. Results in clotting factor dilution and worsens hypothermia
- Acidosis- secondary to shock; further inhibits proper clotting factor function worsening coagulopathy
Procedures Performed—Exploratory Laparotomy; repair of extensive liver laceration; control of liver hemorrhage

Initial incision—required x 4 quadrant packing

Extensive hemorrhage from RUQ—extensive liver injury involving most of right lobe

Spleen—intact

Bowel—no evidence of injury

Bladder—intact

No retroperitoneal hematoma seen

Multiple maneuvers for hemostasis control—packing, sutures, Pringle maneuver x 2, Evarrest fibrin sealant patch

MTP initiated

Right hepatic artery embolization by IR

Liver packed; abd open; protective plastic over bowel, Blake drains x 2, towels and sponges, secured with tape

Anesthesia:

• GA

• Vasopressin infusion

• Epinephrine infusion

• Norepinephrine infusion

• TXA infusion: 200 units/hr

• THAM: 175 mL

• Insulin: 60 units

• Sodium bicarbonate: 18 amps (900 mEq)

• Calcium: 22 grams

• Crystalloid: 4 liters

• EBL: 11 liters

• Arterial Line x 2 (right femoral/left radial)

• CVL x 2 (Right and Left IJ Cordis)

• PRBCs: 56 units

• FFP: 39 units

• Platelets: 10 units (single donor)

• Cryoprecipitate: 8 units

Blood Transfusion Safety

• James Blundell (1790-1877): “Father of modern blood transfusion”; first person to transfuse human blood; experiments proved that transfusing blood from another species was dangerous.

• 20th Century discoveries: practical anticoagulation; ABO blood groups

• Blood Donation: appropriate selection of donors to reduce high risk for transfusion infections with range of testing

• Processing: separation into component parts (RBC, plasma, plt); may extend from minimal separation into components with selective leuco-filtration to universal filtration with pathogen reduction methods

Mass Transfusion Protocol (MTP)

• DCR principles in retrospective studies independently associated with reduced mortality in adults with traumatic and intra-operative bleeding

• MTPs have been developed to implement some aspects of DCR

• Some institutions apply MTPs to all patients with massive bleeding

• MTPs in children—literature is scant; case reports, feasibility studies

MTP and Children

• DCR principles utilized with adults have been applied to children

• Children: reduced blood volume compared with adults may not tolerate large blood volume losses relative to a similar injury

• Lack of cardiac and vascular disease may permit for increased ability to compensate during hemorrhagic shock

• Hemostasis—changes through infancy and puberty implications for safety and efficacy of hemostatic therapies

—Use of hemostatic agents: TXA and prothrombin complex concentrates may have an improved safety profile in children

James Blundell (1790-1877): “Father of modern blood transfusion”; first person to transfuse human blood; experiments proved that transfusing blood from another species was dangerous.
MTP and Children

- Triggers: massive blood loss with profound shock, refractory hypotension NR to 40mL/kg of PRBC, prolonged PT, decreased fibrinogen, decreased plt during resuscitation (Pickett, 2011)
- Definition of mass transfusion- not defined for children; most common: admin of 50% of circulating blood volume= threshold of 40 mL/kg of all blood products given/24 hrs (Neff, 2015)
- Successfully differentiates risk for pediatric trauma patients at risk for early and late death
- Fixed ratio of PRBC: FFP: plt: cryo based on patient’s weight (uncertain what that ratio is)
- Higher plasma/PRBC and higher platelet/PRBC ratios: not associated with increased survival in children (Nosanov, 2013)
- No improvement in mortality after MTP consideration for injury severity, PT and PTT (Hendrickson, 2012)
- No clear survival benefit with MTP use and early FFP (Neff, 2015)

Pertinent Physical Exam: PICU

- Vitals: T 98 Fx, HR 130, BP 150/110, RR 20, SpO2 99% on FiO2 1.0
- Gen: well developed, well nourished male, sedated, intubated, open abdomen
- HEENT: NCAT, orally intubate; OP with blood tinged secretions with MMM. OGT, nares with blood tinged; pupils 3 mm/#brisk
- NECK: trachea midline, cervical collar
- CV: tachycardic, nl S1, S2. No m, rubs, gallop. Pulses/perfusion intact.
- RESP: bilateral BS coarse throughout, Right and Left CT with + air leaks
- ABD: distended, open covered with lap pads and tape, OGT with minimal drainage
- GU: Tanner V; foley in place, clear yellow urine, no blood at meatus noted
- SKIN: Pink, warm and dry. PIV x 2, right SCL TLC, Right femoral sheath, left femoral cordis, right radial arterial line
- NEURO: intubated, sedated with minimal responsiveness, occasional spontaneous movement; MAE with stimulation, no seizure activity noted

Labs- Initial Post-Op

- ABG: 7.21/45/41/-BE 9.6
- Lactate: 10.5 (peak 13 in OR)
- PT: 29.5
- INR: 2.73
- PTT: 89
- Fibrinogen: 153
- Glucose: 112
- Ca: 11.4/ iCa 1.4
- T. bili: 0.3
- Mg: 1.1
- PO4: 2.2
- AST: 572
- ALT: 789

OR Course #2 (HD #1)

- Procedures Performed:
  - Opening of recent laparotomy
  - Abdominal re-exploration and washout
  - Inspection reveals: majority of injury at segments 5,6,7 & 8 with large bleeding vessel at fracture site of 6. Site sutured, approximated and vessel ligated
  - Re-inspection of entire bowel
  - Several areas of liver with oozing- Nu-knot applied and packing with lap pads
  - Viscera covered with ABThera and wound VAC

- Anesthesia : 1825-2015
- GA
- Dilaudid: 1 mg
- Ancef: 1 gram
- Crystalloid: LR 2300 mL
- Cell Saver: 391 mL
- PRBCs: 2 units
- EBL: 500 mL
- Urine output: 250 mL

Question

Which patient is at higher risk for a thromboembolic event?

A. MTP
B. Non- MTP

Thromboembolism

- Goal of MTP:
  - Maintain platelet count > 50,000
  - Maintain hemoglobin level > 10 mg/dL
  - Normalization of coagulation assays (including fibrinogen)
- MTP vs Non-MTP:
  - No difference in mortality
  - Similar amounts of crystalloid
  - Transfused FFP/PRBC in similar ratio
- Non-MTP: 12% incidence of thromboembolism
- None received blood products in 1:1:1 ratio, under transfused, leading to coagulopathy and thromboembolic event
- Warrants further research of MTP in pediatrics

Hospital Course

- Grade V liver laceration, TBI, Hemopneumothorax
- MTP with refractory DIC
- Mechanical Ventilation x 13 days
- Bilateral CT – d/c left- HD# 20 , right-HD #30
- OR multiple times (x 7)
- Subsequent washouts, open cholecystectomy (necrotic), Wittmann patch, omental buttress of right hepatic lobe, abdominal closure
- ERCP with stenting of common bile duct
- Intrahepatic biloma with IR drain placement
- Discharge Home HD #31, with abdominal drains

Question

Should MTP be used to extend the benefits beyond the hemorrhaging child?
A. Yes
B. No
C. I don't know

MTP and Nonsurvivable Injuries

- MTP can affect the viability of organ donation
- Non-MTP: nonsurvivable injuries, rejected as an organ donor owing to severe hemodilution
- MTP: used to maintain viability of organs in setting of nonsurvivable injuries; 4 organs in addition to heart valves, skin and long bones procured
- Resource utilization vs potential impact on donor recipients

Outpatient Follow Up

- 1/1: Hospitalized x 31 days for grade V liver laceration
- 2/1: discharged to home
- 3/28: repeat ERCP with continued leak
- 4/25: abdominal drains discontinued
- 5/15: return to work
- 5/17: discharged from Trauma Service

Pediatric Trauma: What Happened in That Chest?

Valerie Eichler RN, MSN, CPNP-AC/PC
Pediatric Nurse Practitioner
Critical Care Services
Children's Health System
Children's Medical Center Dallas
History & Physical

- **Chief Complaint**: AG is a 12 mo old female involved in MVC @~2130
- **HPI**: Reportedly restrained in car seat, drivers side backseat of car
  - T-boned on driver’s side while stopped at traffic light
  - 4 other adult passengers
  - 911 called
  - Patient had episode of epistaxis
  - Mother flagged down passerby and they transported by POV to OSH ED
  - CPR (both compressions & rescue breathing) performed by Mother in route
  - Arrived to OSH ED @ 2155
  - Limp, agonal, no spont movement, HR:70, GCS:4
  - IO & PIV placed
  - Intubated 1st attempt, emesis during intubation

Energy in MVCs

- The amount of energy and the direction of impact are major factors that determine the outcome of a crash

Location of Impact

- Direct injury to the region closest to the point of impact
- Severity of TBI and thoracic injuries increases
- Cardiac trauma comprises ~3% of overall blunt injuries
- Low incidence may be r/t mobility of the mediastinal structures

Specifically Cardiac Trauma

- Myocardial Contusion
- Commotio Cordis
- Valvular Injury
- Septal Injuries
- Coronary Artery Injuries
- Pericardial Injuries
- Great Vessel Injuries

Question

1) AG rolls in to your emergency department, what is your priority?

   a) Establish IV and send trauma labs
   b) Obtain CXR
   c) Obtain CT of head, chest and abdomen
   d) Secure airway
   e) Transcutaneous pacing

OSH Course

- Labs
- CXR
- CT head/chest/abd
- 20ml/kg NS bolus
**OSH Labs**

- WBC: 9.4
- Hgb: 9.4
- Hct: 30.7
- Plt: 224
- Na: 134
- K: 2.5
- Cl: 103
- CO₂: 15
- BUN: <3
- Cr: <0.2
- Glucose: 500
- Lactate: 6.24
- iCa: 1.28
- ABG: 7.18/42.5/42/6/16.5/11/100
- UA: SG: 1.015, 2+ protein, 2+ glucose, 3+ blood

---

**Arrival to Level 1 Trauma Center**

- Deemed stable for transport by OSH facility
- Children’s transported to our ED
- Labs obtained
- CXR obtained

---

**ED Visit**

- ETT and sump were retracted
- Cardiology consulted and ECHO ordered (concern for pericardial effusion on OSH CT chest)
- More labs obtained
- Repeat CXR obtained
- OSH scans uploaded
- Placed on Fentanyl gtt
- Transferred to PICU @3am

---

**ICU History & Physical**

- Weight: 10Kg
- Height: 31.5 in/80cm
- Medications: None
- Allergies: NKDA
- PMHx: None, term neonate
- PSHx: None
- Family Hx: Unknown
- Social Hx: Unknown
- ROS: no fever, increased WOB, tachycardia
- Last Meal: Unknown
- Time of Injury: 2130
- Mechanism of Injury: MVC, t-boned on driver’s side, reportedly restrained in car seat on driver’s side backseat of car

---

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---

**ICU Progression**

- Stable overnight
- Required multiple Fentanyl boluses and increasing gtt to keep intubated
- Neurologically intact
- Hemodynamically stable
Question 2

2. AG is awake, reaching for her mother, hemodynamically stable. Would you extubate at this point?
   a) Yes
   b) No
   c) Unsure

ICU Plan

- Monitor blood pressure
- ERT and extubate in the AM
- F/U official over reads

ICU

Shift change!!

Radiology

- OSH CT Chest
  - Large pericardial effusion w/o clear etiology. No active extravasation or vascular injury identified in the chest, abd, pelvis
- Radiology over read:
  - There is a large pericardial effusion tracking superiorly into the superior mediastinum and lower neck. There appears to be irregularity and injury of the left subclavian artery with active extravasation as the left subclavian artery passes over the first rib. This does differ from the outside impression
Question 3

3) Now would you extubate?
   a. Yes
   b. No
   c. Unsure

My ICU Plan @ 0730!

- Leave intubated
- Continue sedation
- ECHO reviewed with Cardiologist
- Place arterial line
- F/U official over reads with attending radiologist

ICU Plan

- ICU attending agreed with leaving patient intubated
- Discussed CT with attending radiologist @ 0930
- Decided CTA was best study for evaluation of possible SCA injury
- CTA ordered @ 0930
- N-acetylcysteine ordered
- Discussed with Trauma attending
- Cardiology reconsulted
- Cardiothoracic surgery consulted

Case Progression

- VS: HR 158 RR 30 BP 108/61 SpO2 98 ETCO2 51 T 36.8
- H/H 10.5/33.3
- Troponin 1 6.9
- Sitting outside patient’s room @~1100
- Transport ready and patient is halfway out of the room
- Change in the sound on the ECG detected

Asystole!!

- Bradycardic -> Hypotensive -> Asystolic!
- Chest compressions x4 min
- 2 rounds of Epi
- 40ml/kg NS bolus

Post Arrest

- Trauma, CTS and Cardiology STAT to the bedside
- ECHO guided pericardiocentesis performed
  - <5ml of blood obtained
- TEE with small effusion
  - Stable sized hemopericardium with thrombus evident, good function, no evidence of tamponade
Post Arrest

- Became profoundly hypoxic
- Bagged 100% FiO2
- Pink frothy ETT secretions
- Switched to PC mode
- PEEP increased to 14
- iNO added

Procedures/Interventions

- Femoral CVL
- Femoral Arterial Line
- CTS makes decision to take to the OR for pericardial window

Intraoperative Course

- Subxyphoid approach for pericardial window
- Large thrombus located in the posterior portion of pericardium, suctioned without issue
- Suctioned turned to anterior portion of pericardium and a clot was removed resulting in rapid blood loss
- Converted to open median sternotomy
- Heparinized for bypass

What was the cause of the exsanguination?

- ~1.5cm tear at the base of the RA appendage
- Clamp placed and 4.0 Prolene suture was purse stringed and snared around the defect, hemostasis obtained and clamp was removed
- Reversed heparinization
- EBL: 1000ml
- PRBCs 650ml FFP 300
- Junctional rhythm after near exsanguination requiring atrial pacing x3 days
Intraoperative ECHO

POD 4
- Extubated to HFNC 6 lpm
- TC Seizure with eye deviation
- Ativan x2 and loaded with Levetiracetam
- MRI obtained for concern for stroke
- Neurology consult
- Video EEG x36 hours: no seizures

MRI/MRA
- MRA unremarkable
- MRI Global ischemic injury

Discharge to Home
- Discharged home on POD 8
- Neurologically appropriate, no further seizures

6 month Follow Up
- No further seizures
- Mother feels she is using her left hand less than right
- Per Neurology notes is developmentally on target
- Plans to wean Levetiracetam off if seizure free for 1 year

Summary of Cardiac Trauma
- Most presents as multisystem involvement
- Cardiac trauma makes up ~3% of the trauma
- Thoracic trauma makes up ~10% of all pediatric trauma
- Overall mortality of 12%
- Most cardiac trauma is due to blunt force with MVCs being the cause of the majority of the injuries
- Mobility of the mediastinal structures may be the reason cardiac trauma is so rare
Hemopericardium

- Develops from:
  - Tear in the myocardium
  - Laceration of parietal pericardium
  - Laceration of epicardial surface

Hemopericardium

- Most often associated with injury to the right ventricle secondary to the thin ventricular wall
- Can be acute or slow accumulation of blood

Physical Findings

- Beck’s Triad
- Pericardial Rub
- Pulsus Paradoxus
- Cyanosis or Hypoxia
- Tachypnea

Beck’s Triad

- Jugular vein distention
- Distant or muffled heart tones
- Hypotension

PEARLS

- Always listen to your intuition
- CXR not reliable to r/o pericardial effusion/hemopericardium
- Best way to r/o tamponade is with ECHO
- Have team approach and plan

- Sincere thanks to the following individuals for their contribution to this talk:
  - Amy L. Juraszek, MD, FAAP, FACC
  - Paul Brown RDMS, AE, PE, FE
  - Kristine J. Guleserian, MD
  - Timothy J. Piroli, MD
  - Stacey Scott, RN, MSN, CPNP-AC/PC
Pediatric Trauma: the Head

Lauren Sorce RN, MSN, PhD(c), CPNP-AC/PC, FCCM
APN Manager, Critical Care

Case Study

• Chief complaint: shortness of breath
• JJ is a previously healthy 6 month old F admitted after sustaining a fall from a changing table. She cried at first then became quiet and began agonal breathing. 911 called and upon arrival, Dad was rescue breathing for her as directed by EMS operator.
• Cervical spine stabilized, IV access obtained
• Taken to OSH ED

Case Study Physical Exam ED

• VS: T 34.8°C, HR 182, BP 92/54, RR 29 (BVM), SpO₂ 100%, 6.8kg
• GEN: lethargic, cold toddler
• HEENT: normocephalic, atraumatic, no cranial deformities, hematoma or skull depression, no swelling or signs of injury, conjunctiva clear, no rhinorrhea, OP clear, tongue dry, bil TM pink, no ear drainage
• NECK: in c-collar
• CARDIAC: tachycardia with RR, no M appreciated, pulses weak
• RESP: accessory muscle use, nasal flaring and stridor, rhonchi
• ABD: soft, normoactive bowel sounds, no HSM
• GU: nl external female genitalia
• EXTREMITIES: perfusion >5 seconds
• SKIN: eczema noted on rt anterior mid arm
• NEURO: Pupils PERRL and brisk. Lethargic

Question #1

• What are the most appropriate interventions?
  – A. access, fluid resuscitation, head CT, intubation, warming
  – B. access, intubation, head CT, fluid resuscitation
  – C. head CT, access, intubation, fluid resuscitation, warming
  – D. intubation, head CT, fluid resuscitation, access

Disclosures

• None
Case Study

- ED interventions:
  - Intubation for GCS 4 using ketamine
  - Additional IV insertion (infiltrated I/O)
  - Fluid resuscitated (60ml/kg)
  - Radiology
  - Labs

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Glasgow Coma Score

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<td>V (Verbal)</td>
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<tr>
<td>R (Rigidity)</td>
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Case Study-Radiology Results

- CXR: Perihilar interstitial and patchy opacities, left > right. ETT above clavicles
- CT Head w/o Contrast
  - Diffuse cerebral edema
  - Subdural hemorrhage along the left hemispheric convexity extending along the intrahemispheric fissure and tentorium
  - Subarachnoid hemorrhage along the right parietal lobe
  - Mass effect with 4 mm of rightward midline shift
- CT Spine w/o Contrast
  - Unremarkable CT examination of the cervical spine with no evidence of a fracture and no subluxation
- CT Abdomen and Pelvis W Contrast
  - No evidence of acute traumatic injury within the abdomen or pelvis.
  - Mild bilateral pelvicaliectasis, likely related to bladder distention.

Epidemiology

- Graph showing the rate of TBI-related ED visits and hospitalizations by age group from 2001 to 2010.
Case Study

- JJ is transported via ambulance to children's hospital
- En route, she develops a fixed, dilated left pupil

Question #2

- This is child is an infant. Can she experience intracranial hypertension?
  - A. Yes
  - B. No

Question #3

- What do you think is happening?
  - A. Her subdural is expanding
  - B. Her cerebral edema is worsening
  - C. She is agitated
  - D. She is hypotensive

Question #4

- What therapeutic intervention should you use for this condition in this patient?
  - A. Bolus fentanyl
  - B. Bolus mannitol
  - C. Bolus 3% hypertonic saline
  - D. Bolus pentobarbital

Intracranial Dynamics and Key Concepts

- Autoregulation
  - Vasodilation and vasoconstriction maintain steady CBF despite BP fluctuations
- Compliance
  - Change in pressure resulting from a change in volume
- Cerebral blood flow
  - Physiologic influencers are PaCO₂, PaO₂, pH, CPP and CMR
Monro-Kellie Principle

- Cranium is a fixed vault
- Contains 3 compartments
  - Brain ~80%
  - Blood ~10%
  - CSF ~10%

Pediatric TBI Guidelines-Hyperosmolar Therapy

- Strength: weak; Quality: moderate
- Hypertonic Saline
  - Level II evidence
    - Consideration of 3% hypertonic saline for TBI-associated intracranial hypertension at doses of 6.5-10mL/kg
  - Level III evidence
    - Consideration of 3% hypertonic saline for treatment of severe TBI-associated intracranial hypertension as continuous infusion at 0.1-1mL/kg/hr
    - Minimum dose to reduce ICP to <20mm Hg
    - Maintain serum osmolarity <360mOsm/L
- Mannitol → No studies meeting inclusion requirements identified

Effectiveness of Pharmacological Therapies for Intracranial Hypertension in Children With Severe Traumatic Brain Injury—Results From an Automated Data Collection System Time-Synched to Drug Administration

- Prospective observational study
  - n=16 children who received 196 doses of fentanyl, hypertonic saline, mannitol, and pentobarbital
  - Similar GCS across all children in study
- Evaluated intracranial hypertension reduction and maintenance of CPP

Fentanyl and Midazolam Are Ineffective in Reducing Episodic Intracranial Hypertension in Severe Pediatric Traumatic Brain Injury*

- Retrospective analysis
  - n=31 children with 413 episode of ICH
- Evaluate effectiveness of fentanyl and midazolam in reduction of ICH
- Administration of bolus dose fentanyl and midazolam did not improve ICH
- In fact, bolus doses of high dose fentanyl, low dose midazolam and high dose fentanyl + low dose midazolam increased ICP
Pediatric TBI Guideline: Cerebral Perfusion Pressure

- Strength: Weak; Quality: Low
- No sufficient level I or level II data.
- Level III
  - Minimum CPP 40 mmHg in children with TBI
  - Consider threshold of 40-50 mmHg
  - May be age specific thresholds for infants (low end) and adolescents (high end)
- Survivors of TBI have higher CPP than non-survivors
- Yet, there’s no study that targets CPP threshold that demonstrates reduced morbidity and mortality

Back to the Case Study

- JJ’s pupillary response improves with administration of hypertonic saline and mannitol while en route
- In the ED at the children’s hospital, she is seen by neurosurgery and the trauma team
- At that time, she has the following exam:

Case Study: Exam after Transport

- Primary Survey
  - Airway: Patent, ETT
  - Breathing: via bag mask ventilation
  - Circulation
    - Cap refill: 2 sec
    - Pulse Quality: 1+ (brachial)
    - Skin Color: Pale, mottled
    - Skin Temperature: Cool
    - Chest Compression: Unknown
  - Disability
    - Unresponsive, GCS
  - Pupil
    - Left: 6 mm in size, non-reactive
    - Right: 3 mm in size, non-reactive
  - Glasgow Coma Scale (GCS)
  - Eye Opening: None: 1
  - Verbal Response: No response: 1
  - Motor Response: No response: 1

Case Study

- Order repeat scans, labs and plan for OR
- Taken for evacuation of subdural hematoma
- During the evacuation, the brain swelled significantly and a hemicraniectomy was performed

Question #5

- Should this child have ICP monitoring?
  - A. Yes
  - B. No
  - C. Unsure

Pediatric TBI Guideline: ICP Monitoring

- Strength: weak; Quality: low
- Level I and II insufficient data
- Level III
  - May consider using ICP monitoring in infants and children with TBI
- Suggestion of clinical benefit in literature
- Not routinely indicated for mild or mod TBI but individualized decisions if exam is precluded by medical management
Noninvasive screening for intracranial hypertension in children with acute, severe traumatic brain injury

- Prospective observational study
- Evaluate relationship between transcranial doppler (TCD) pulsatility, end diastolic velocity and ICP
- n=36 children with ICP monitoring underwent 148 TCD studies
- Performed TCDs and measured pulsatility index (PI)
- Identified PI associated with ICP >20 mm Hg

ICP Threshold

- Evidence supporting ICP >20 mm Hg and abusive head trauma associated with poor outcome
- As ICP increases by 1 over 20 mm Hg, odds of worse outcome increase by nearly 5%
- Number of hours with ICP >20 mm Hg and CPP <45 in children <18 y/o best identify who will have poor outcome

Case Study

- Post-operatively, she was brought to the PICU under the care of the following services:
  - Trauma - Pediatric Critical Care
  - Neurosurgery - Neurocritical Care
- She had a CVL, arterial line, external ventricular drain (EVD) and another PIV placed, ETT and OG
- She proceeds to have ICH and receives continuous infusion of 3% HTS and intermittent boluses
- She is sedated and muscle relaxed

Pediatric TBI Guideline: Sedation, Analgesia and Neuromuscular Blocking Agents

- Use evaluated in reference to intracranial hypertension not necessarily comfort, pain relief or decreased metabolic demands
- Strength: weak; Quality: low
- Level I and II insufficient data
- Level III (based on 2 studies)
  - May consider etomidate to control ICH while considering risk of adrenal suppression
  - May consider thiopental to control ICH

Effect of Administration of Neuromuscular Blocking Agents in Children With Severe Traumatic Brain Injury on Acute Complication Rates and Outcomes: A Secondary Analysis From a Randomized, Controlled Trial of Therapeutic Hypothermia

- Analysis of children who received NMBA while enrolled in Cool Kids study in regards to outcomes, ICH and medical complication
- n=90 children with similar demographics and intervention vs control group in primary study
- NMBA use associated with ICH interventions and consistent use associated with increased ICU LOS
- No association with increased medical complications
### Case Study

- Management includes the following:
  - Comfort management
  - Ventilatory support
  - Peri-operative antibiotics
  - Neuro management
  - Nutritional support*

### Neuro Management

- Maintenance of:
  - Avoidance of fever
  - Na >145
  - Prevention of hyper- and hypoventilation (PaCO₂ 35-40)
  - Euglycemia BP wnl for age
  - ICP<20, CPP >40
  - Seizure prophylaxis (level III evidence)
  - Frequent neuro checks

*Smith et al, PCCM 2012; 13:85-91

### Comparison of hypothermia and normothermia after severe traumatic brain injury in children (Cool Kids): a phase 3, randomised controlled trial

- RCT enrolling children <18 y/o within 6hrs TBI evaluating mortality and global function at 3 months and serious adverse events
- n=77 children
- Intervention → rapidly cooled children to 32-33°C for 48-72 hrs then rewarmed over 12-24hrs
- Control → Temp controlled at 36.5-37.5°C
- All other management similar
- Ended for futility → no difference in mortality or global functioning


### Cool Kids Outcome

- Smith et al, PCCM 2012; 13:85-91

### Just a little bit on outcomes after TBI . . .

- Analysis of long-term (median 10.5 years) outcomes in children presenting with traumatic brain injury and an initial Glasgow Coma Scale score of 3 or 4
  - Retrospective review of prospectively collected data
  - Evaluating long term outcomes
  - n=67
  - 71% died, remained vegetative or were severely disabled at 1 yr
  - 12% were nl at 1 yr
  - 22 subjects had 10 yr f/u and 10/22 were nl or high functioning

Summary

- Traumatic brain injury remains a significant pediatric problem
- Overall, the 2012 pediatric guidelines lack level I and II evidence
- This is an indication that much of our work still needs research

Thank you!

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