Case Presentation:
Pediatric Trauma

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HPI

- 4yo healthy male
- MVC: head-on at 65mph
- Back seat passenger
- Restrained by lap belt
- Crying at the scene
- Unable to move lower extremities
- Taken to outside hospital
Outside Hospital

- Hypotensive
  - 2 units pRBCs, 800ml NS
- hct: 18.5  INR: 1.72  7.24/30/349/13/-13
- Intubated
- Dislocated right ankle
  - Reduced and splinted
- Head CT – normal
- Chest CT – normal
- Abdominal CT…
Abdominal CT

- Aortic thrombosis extending into bilateral iliacs
- L2 Chance fracture
- Free abdominal fluid
- Mesenteric injury
- Right sided abdominal wall rupture
Transfer to TCH

- 100cc pRBCs enroute
- Arrived approx 3 hours since MVC
- ABG: 7.03/49/63/13/ BE -18
- Hct 24.7 platelets 208
- PT 19.1 INR 1.58 PTT 35
- Additional fluid resuscitation
- Placement of left chest tube for effusion
- To OR
Emergent Exploratory Laparotomy

- Evacuation of intraperitoneal blood
- Ligation of bleeding mesenteric vessels
  - Multiple mesenteric tears
- Packing of right abdominal wall disruption
Emergent Exploratory Laparotomy

- **Aortic repair**
  - Longitudinal aortotomy
  - Complete circumferential transection of the intima below IMA, sliding inferiorly and occluding bilateral iliacs
  - Distal intima pulled up and tacked down
  - Distal thrombectomies
  - Aorta closed longitudinally with running prolene
Emergent Exploratory Laparotomy

- Traumatic transection of the terminal ileum from the cecum
- Resection of devascularized bowel
  - Included some ascending colon
- Three segments of closed-loop bowel
  - Vented with drains
- Open abdomen
Emergent Exploratory Laparotomy

- Prophylactic bilateral lower extremity fasciotomies
- Right chest tube for effusion

- To PICU on dopamine and epinephrine
  - ABG: 7.36/35/67/20/ BE -5.5
  - Hematocrit: 39
  - Platelets: 109
  - INR: 1.17
Emergent Exploratory Laparotomy

- **EBL:** 3 Liters
- **Fluid Replacement:**
  - 14 units pRBCs
  - 1 liter FFP
  - 13 platelet random donor units
  - 2.4mg Factor VIIa
  - 6.5 L crystalloid
  - 500ml Albumin
- **UOP:** 1800ml
POD #1

- Continued resuscitation
- Profound respiratory failure/ARDS
  - Hypoxemia
  - Switched from conventional ventilation to High Frequency Oscillatory Ventilation (HFOV)
  - Improved respiratory status
- Taken back to OR for decompensation
  - Resection of necrotic ileum, ascending colon, and left colon
Postoperative Course

- Abdominal washout POD #1 and #3
- Abdominal closure POD #5
  - 115cm of proximal small bowel ends as jejunostomy
  - Transverse colon mucous fistula
  - Hartmann’s pouch
- Fevers POD#10
  - Candida from tracheal aspirate
- Extubated POD #14
Postoperative Course

- Spinal fusion on POD #33

- Currently
  - Awake and alert
  - Abdominal wound closed
  - PO intake + tube feeds
  - Paraplegia
    - Approx T10 level
Seat Belt Syndrome

- Garret and Braunstein in 1962
- Hip and abdominal contusions
  - “seat belt sign”
- Pelvic fractures
- Intraabdominal injuries
  - Solid and hollow viscera
- Lumbar spine injuries
  - Subluxations and compression fractures L2-4
Abdominal Wall Ecchymosis

- 2004 *J Pediatric Surgery*: Lutz et al.
- 147,985 children in 102,548 crashes
- Occurred in 1.33%
  - Intraabdominal injury occurred in 11.5%
  - Significant intra-abdominal injury 232 times more likely
- Sensitivity – 73.5%
- Negative predictive value – 99.9%
Mechanism of Injury

- Improper position of lap belt serves as a fulcrum during rapid deceleration
  - Spine hyperflexes
  - Direct pressure on abdominal viscera
Presubmarining and jackknifing

Classic submarining

Submarining/jackknifing
Intra-abdominal Injuries

- GI tract perforations
- Small bowel mesenteric tears
- Solid organ injury
- Due to direct compression
Lumbar Spine Injuries

- Compression fractures
- Chance fractures
  - Horizontal fractures
    - Spinous process
    - Pedicles
    - Vertebral body
  - Rupture of posterior ligaments in up to 50%
Seat Belt Aorta

- Dissection of the intima caused by direct compression of the vessel between the horizontal part of the seat belt and the vertebrae.
- Described in 1979 by Dajee et al.
- Two forces
  - Direct compression
  - Indirect shear forces
Seat Belt Aorta

- **Blunt injury to abdominal aorta is uncommon**
  - Aortic injury after blunt trauma occurs in 10-15%
    - <5% involves abdominal aorta
    - 1997 *J Trauma* – 62 reported cases

- **Commonly associated injuries**
  - Seat belt sign – 47%
  - Bowel injury – 47%
  - Lumbosacral spine injury – 35%

- **Mortality rate 24%**
Seat Belt Aorta

- Recognized abnormalities
  - 39% - intimal injury with acute and complete vessel occlusion
  - 16% - intimal tears without occlusion
  - 15% - true aneurysms
  - 5% - aortic rupture
Aortic Occlusion Secondary to Blunt Trauma

- 2002 *J Trauma*: Meghoo et al.
  - 36 reported cases
- 78% cases from MVCs
- Prolapse of distal intimal flap after circumferential tear
- Accompanying subintimal thrombus
  - Higher incidence in atherosclerotic disease?
- Mortality 41%
Our Patient

- **Rare injury triad**
  - Abdominal aortic injury
  - Lumbar Chance fracture
  - Mesenteric/visceral injuries

- **12 reported cases in pediatric patients**
  - 2006 *J Trauma*: Choit et al.
  - All secondary to MVCs
  - 7 lap belts
  - 5 unknown restraints
Proper Restraints

- 2007 *Journal of Trauma*: Arbogast et al.
- Restrained children with abdominal organ injuries
- Low injury rates in other vehicle occupants
  - 40% drivers
  - 10% other child occupants
- Suboptimal restrained kids 3.8 times more likely to suffer intraabdominal injury
High Frequency Oscillatory Ventilation (HFOV)

- Introduced in 1972
- Reciprocating pumps or diaphragms
  - Active inspiration and expiration
- Small tidal volumes ($V_{ts}$)
- Higher mean airway pressure (mPaw)
  - Limits alveolar derecruitment and overdistention
- Rapid respiratory rates
  - Adequate gas exchange
Schematic representation of the purported waveforms of HFOV and conventional pressure-controlled ventilation in the distal airways

HFOV

- Oscillating piston pump (or diaphragm)
  - 180 to 600 breaths/min (3 to 10 Hz)
  - Active inspiration and expiration
- Inspiratory bias gas flow (30 to 60 L/min)
  - mPaw
- Resistance valve
  - mPaw
- Oxygenation
  - FiO2 and mPaw
- Ventilation
  - Respiratory frequency and pressure amplitude
Mechanism of Gas Transport

- Conventional Mechanical Ventilation (CMV)
  - Convective or bulk flow
- HFOV
  - Convective and diffusive
    - Bulk flow proximally
    - Asymmetric velocity profiles
    - Taylor dispersion
    - Pendelluft
    - Collateral ventilation
    - Cardiogenic mixing
1) Direct Bulk Flow.
2) Longitudinal (Taylor) dispersion
3) Pendelluft
4) Asymmetric velocity profiles
5) Cardiogenic mixing
6) Molecular diffusion

Proposed mechanisms of gas transport during HFV

Ventilator-Induced Lung Injury

- Increased in ALI/ARDS
- Barotrauma
  - Secondary to pressure
- Volutrauma
  - Alveolar overdistention
  - Distributed to compliant lung
- Atelectrauma
  - Parenchymal injury
  - Repetitive opening/collapse of distal airways
HFOV

- Lung-protective strategies developed
  - HFOV may be ideal
- Comparatively higher mPaw
  - Allows recruitment/prevents derecruitment
  - Higher end-expiratory lung volume
- Lower tidal volume
  - Gas exchange at lower airway pressures
  - Limits alveolar overdistention
  - Less cardiovascular effect
- “Open Lung” concept
  - Maintains open airways
HFOV

- **Conversion to HFOV**
  - Peak pressures $>35$ cm H$_2$O
  - $mPaw$ approaches 15 to 18 cm H$_2$O
  - $FiO2 > 0.6$

- **Better to convert earlier?**
  - # of days on CMV was an independent predictor of mortality

- **Initial settings**
  - $FiO2$: 0.9 – 1.0
  - $mPaw$: 5 cm above last measured $mPaw$ on CMV
  - Bias flow: 40 L/min
  - Consider recruitment maneuvers
PRCT: CMV vs HFOV

  - 148 adults, 13 centers

- HFOV: earlier improvement in PaO2/FiO2 ratio
  - <16 hours
  - Did not persist beyond 24 hours

- HFOV: nonsignificant trend toward lower 30-day mortality
  - 37% vs 52% (p=0.102)

- Similar but low adverse events

- Prior to ARDS Network trial
  - VTs 10ml/kg used
ARDS in Surgical Patients

- 16 surgical patients with ARDS
  - Oxygenation failure
- HFOV: significant findings
  - Increased PaO2/FiO2 ratio after 30 min
    - Maintained after 12 hours out to 40 hours
  - Oxygenation index decreased at 24 and 32 hrs
    - OI [ FiO2 x mPaw x 100 / PaO2 ]
- No change in systolic BP
- No complications
- No pediatric studies to support lung protective strategy in ARDS
- Most HFOV studies looking at neonates
- Jaballah et al, 20 patients
  - Failed CMV, switched to HFOV
  - After 1 hour
    - Improved ventilation in all 20
    - Improved oxygenation in 19/20
  - Only 1 death from respiratory failure
HFOV Summary

- 2007 review of HFOV in ARDS
- 2 PRCTs and 12 case series
- Safe and consistently improves oxygenation when used as rescue mode for ventilation
- Delayed initiation of HFOV is an independent predictor of death.
- Trend towards lower mortality
AAP - Car Seat Guidelines

- Rear-facing seat
  - Infant ➔ 1 year and 20 lbs

- Forward-facing seat
  - Until 3-5 years old or 40-60 lbs

- Booster seat with lap/shoulder belt
  - Until approx 8-12 years old
  - Until 4’ 9”

- Seat belt
  - Shoulder belt crosses mid chest
  - Lap belt across upper thighs, not stomach
  - Knees bent over seat
References