Pulmonary Trauma Case Studies

John J. Gallagher MSN, RN, CCNS, CCRN, RRT

Trauma Program Coordinator/Clinical Nurse Specialist
Division of Trauma, Surgical Critical Care and Emergency Surgery
Hospital of the University of Pennsylvania
Chest Trauma

Accounts for 25% of all trauma deaths

- Airways
- Pulmonary
- Cardiovascular
- Digestive tract
Mechanism

Blunt
- Fall
- MVC
- MCC

Penetrating
- Blast Injuries
- GSW
- SGW
- SW
- Impalement
Management Approach

Initial Assessment / Intervention / Resuscitation

Diagnostics

Operative Intervention

Supportive Care

Prevention of Complications
Injury

• 20 y/o. male collegiate cyclist struck by auto
  – Injury at 1530

• Prehospital
  – Transported by Philadelphia Fire-Rescue
  – Trauma system activation – 1558
  – Patient arrival at HUP – 1607
  – Report stated pt was struck then run over by a dump truck
Primary Survey

• Airway —
  – Patent
  – Complaining of pain

• Breathing —
  – Decreased breath sounds left chest
  – Palpable crepitus bilaterally

• Circulation —
  – Tachycardic
  – Palpable femoral pulses

• Disability —
  – GCS 15
  – Moving all extremities

• Exposure —
  – Tire marks across his chest
Initial Assessment

• Vital Signs – HR 111, RR 40, BP 98/53, SpO₂ 88% on 100% non-rebreather

• Due to respiratory distress
  – planned urgent endotracheal intubation with simultaneous bilateral chest tube placement

• RSI attempted
  – Rapid desaturation
  – Attempted bag-mask ventilation
  – SpO₂ as low as 19%
  – Progressed to sinus bradycardia
Interventions

- Cricothyroidotomy with increased SpO₂ after 30 seconds
- Bilateral chest tubes placed
  - Left hemothorax - <100 ml blood, no air leak
  - Right hemothorax – 200 ml blood, small air leak
Auto-transfuser Chest Drainage System

• Designed to collect and transfuse the patients’ blood from the thoracic cavity
Assessment

• Secondary Survey
  – Right facial abrasions
  – Right eye proptosis
  – Left middle finger PIP open dislocation

• FAST
  – Negative, pericardial view limited by subcutaneous emphysema

• Improvement in vital signs with fluid resuscitation and mechanical ventilation
Injuries

• Bilateral pulmonary contusions secondary to severe crush injury
  – Bilateral pneumothoraces with pneumomediastinum
  – Right 6-10th, left 2-5th rib fractures
  – Left clavicle fracture
  – Right scapular fracture
• Grade I splenic laceration
• Facial fractures
• Fractures of left hand
• No evidence of great vessel injury
Transfer

• Transfer to the SICU
  – Continue workup
    • Flexible bronchoscopy
    • Esophagoscopy
  – Poor oxygenation
    • 7.18/64/63/-3.8/86% (drawn at 1830)
Pulmonary Contusion

Force

Compression

Expansion/Implosion

Separation of Tissue Layers
Pulmonary Contusion

Injury

Inter-alveolar bleeding/Surfactant dysfunction

Alveolar Collapse ➔ Shunt

Hypoxia Hypercarbia (72 hrs)

Resolution ≈ 7 days

Complications
• ARDS
• Pneumonia
Pulmonary Contusion Diagnosis

- CXR under-diagnoses contusion (47% initial)
- CT scan more reliable
Initial Management

- Airway Control
  - Intubation
  - Surgical
  - Invasive
  - NIV
  - ILV
  - Conventional

- Ventilation
  - Tube Thoracostomy

- Circulation
  - Hemorrhage Control
  - Fluid Management
  - Bronchial blockers
    - Amount
    - Type
Volume Control

- LTVV

Pressure Control

- Dual Control
- Bi Phasic
- APRV
- VDR

PEEP
Respiratory Failure

• Repeat flexible bronchoscopy
• Advanced to APRV 12 27/0 100% (2100)
  – Inhaled prostacyclin
  – 7.20/58/59/-4.0/83%
APRV Characteristics

- High CPAP level with a short expiratory releases at set intervals (rate).
- APRV always implies an inverse I:E ratio.
- All spontaneous breathing is done at upper pressure level.
Selective Pulmonary Vasodilators

- Improve ventilation and perfusion matching by improving perfusion to the best ventilated lung regions
- Reduce Pulmonary Vascular Resistance (PVR)
- Reduce afterload of the RV
- Modulators of inflammation and platelet aggregation
Pulmonary Vasodilators

Distribution of gas

- Preferential distribution to ventilated alveoli
- Improvement in perfusion to ventilated areas
Nitric Oxide (NO)
Endothelium derived relaxing factor

- Endogenous production in upper airways
  - vasodilator
  - bactericidal
  - platelet modulator
  - immune modulation (↓IL 6 & 8, Neurophil act.)
Nitric Oxide

Injection of gas into the distal ventilator circuit (minimize interaction with $\text{O}_2$)

- initial 20-40 ppm
- maintain 2-10 ppm

Adverse effects
- methemaglobinemia
- oxidant formation
- vasoconstriction/hypoxemia (withdrawal)
- possibly renal failure
Nitric Oxide Research

• Additive effect of improved oxygenation when NO is combined with prone positioning

• Ability to ↓FiO2 correlated with starting NO ≤ 3d of ARDS and Cs >20.
Prostacyclin
3100B Oscillator
Oscillator
HFOV

Hager (2012) Anesthesiology, 25, 17-23
Alveolar Volumetric Changes During HFO

Conventional

HFOV

Insp.

Exp.

Insp. \approx Exp.
Safe Zone

![Graph showing the relationship between volume and pressure with inflection points labeled as upper and lower.](image)

- Upper Inflection Point
- Lower Inflection Point
Safe Zone

HFOV Breath
VDR Waveform

Images courtesy of Percussionaire Corporation
Tracheobronchial Disruption

- Dyspnea, tachypnea, hemoptysis
- SQ emphysema
- Atelectasis
- *Persistent pneumothorax*
- Pneumomediastinum
Operative Decision

• Not a surgical candidate for bronchial repair due to acute lung injury
• Evaluated for extracorporeal membrane oxygenation (ECMO)

Cannulation

• Cannulated for venovenous ECMO
  – Percutaneous cannulation
    • L subclavian vein: venous drainage
    • R femoral vein: venous return
  – Ventilator
    • AC 8/400/50%/PEEP5
# Pulmonary Indications

**Adult Indications:**

<table>
<thead>
<tr>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total static lung compliance $&lt; 0.5 \text{ ml/cm H}_2\text{O/kg}$</td>
</tr>
<tr>
<td>Transpulmonary shunt $&gt;30%$ on $\text{FiO}_2 \geq 0.6$</td>
</tr>
<tr>
<td>Reversible respiratory failure</td>
</tr>
<tr>
<td>Time on mechanical ventilation $\leq 5 \text{ days (10 days maximum)}$</td>
</tr>
<tr>
<td>Trauma</td>
</tr>
</tbody>
</table>
ECMO

- Improved oxygenation & ventilation
  - 7.34/33/134/-6.0/99%
- Heparin anticoagulation
  - ACT 160-180
- Splenic laceration
  - Serial hemoglobins
  - Serial FAST exams
Evaluation

• Flexible esophagoscopy
• TEE
  – Hyperdynamic
  – EF: 75%
  – No evidence of aortic injury
• Flexible bronchoscopy
  – Bronchial tear had increased in size
• Proceeded to OR for bronchial repair while on ECMO circuit
Positive Pressure and RV Preload

Preload Reduction

– Venous return reduction from positive ITP
  • Reduction in pressure gradient vena cava to RA

– Magnified in hypovolemia
Positive Pressure & RV Afterload

- Myocardial $O_2$ demand
- Reduced Coronary Artery BF (chamber dilation)

PPV/PEEP
- Distention of alveoli
- Capillary compression
- Increased RV afterload

Hypoxic Vasoconstriction
Hemodynamic TEE (hTEE)™
Transgastric Short Axis

- Shape and kinetics of interventricular septum

Small patient

Average patient

Large patient

Superior Vena Cava

GOAL
- To assess volume responsiveness

TECHNIQUE
- Position probe above the aortic valve
- Visualize SVC adjacent to the ascending aorta

ASSESSMENT
- SVC size and collapsibility

ImaCor Inc
Repair

Right Mainstem
Ventilator Management

• Minimization of vent support
  – V-V ECMO continued
  – SvO$_2$ slowly improved
  – Lung compliance improved

• HD #5
  – SIMV 14/PS 10/60%/PEEP 7.5
  – ECMO flows weaned
  – ECMO decannulation late on HD #5
SICU Course

- Serratia pneumonia
- Vent liberated HD #15
- Transferred to floor on HD #17
Case 2

22 y.o. male with a close range \textit{SGW} to the L. anterior chest

\textbf{Wound #1:} 4 ICS, mid-clavicular line

\textbf{Wound #2:} L. mid-axillary line
Case 2

- Awake: GCS 15
- Respiratory rate: 32 labored, visible paradoxical motion L. chest, c/o SOB.
- SQ air over left chest with air movement through the exit wound
- SpO2: 94% on 100% NRB mask
- HR: 120, BP: 116/88
Case 2

Prehospital Treatment

• 100% FiO2 by NRB mask

• Closure of chest wound with occl. dressing

• Two 14g I.V.s with 1000 mls of L.R. infused.
SGW to the Chest

- RSI intubation: 8.0 OETT, placement of OGT
- 36 fr. CT, L. side: 400 cc blood
- Vent: Vt: 550, A/C: 16, 100%., PEEP +5
- 9.0 fr. introducer: 2 units of PRBCs via Level 1
- CXR
- Pt. to O.R.
Injuries

- L. open pneumothorax
- L. flail chest
- L. pulmonary contusion
- Bronchial injury
- r/o Blunt cardiac injury
SGW Chest : O.R. Phase

- Placement of double lumen ETT; Initiation of Independent lung ventilation (ILV)
- L. partial lung resection with insertion of two 36 fr. chest tubes
- Insertion of CCO PAC/A-line
- Crystalloids: 3 liters/PRBCs: 4 units/FFP: 2 units
- EBL: 1500 ccs
Ventilation/Oxygenation Strategies

• Lung protective
  – LTVV
  – PCV – IRV
  – Bi Phasic/APRV

• Independent lung ventilation (ILV)
• ECMO (veno-venous)
Assymetrical Lung Injury
Overdistension of normal alveoli

Shunt

Alveolar Injury

Deadspace

Diagram of alveoli and vessels.
Independent Lung Ventilation (ILV)

• Utilizes two interfaced ventilators

• Simultaneous, but independent ventilation of the lungs via a double lumen endotracheal tube
Independent Lung Ventilation (ILV)
Double Lumen Endotracheal Tube

Photo by John Gallagher
Endobronchial Blockers

Ng et al. (2010) Continuing education in anaesthesia, critical care and pain, 10(4), 117-122.
Double Lumen Endotracheal Tube

Photo by John Gallagher
Independent Lung Ventilation (ILV)

Unilateral Lung Disease
- Pulmonary contusion
- Refractory atelectasis
- Aspiration pneumonia
- BPF with leak

Bilateral Lung Disease
- Pulmonary contusion
- ARDS with differential severity
Considerations with ILV

- Migration of double lumen tube:
  Changes in breath sounds

- End-tidal CO2 monitoring of each lung

- Assessment of individual lung Vt and lung compliance
GSW chest: ICU Phase

- GCS: 3C (post-op neuromuscular blockade)

- Breath sounds: Decreased L. side

- L. Chest tubes to suction: + air leaks

- Vitals: BP: 100/50, HR: 120, Temp: 97 core
SGW Chest

R: normal
Vt: 300 ml
Rate: A/C: 16
FiO2: 1.0
PEEP: +5
PIP: 25 cmH₂O
Ppl: 17 cmH₂O
Cs: 0.050 ml/cm/H₂O

L: Injured
Vt: 200 ml
Rate: A/C: 16
FiO2: 1.0
PEEP: +10
PIP: 40 cmH₂O
Ppl: 35 cmH₂O
Cs: 0.025 ml/cm/H₂O

CXR: L. Pulmonary contusion
ABG: pH: 7.37/36/80/HCO3: 26/-1 SaO2: 94%
SGW Chest

• Large (continuous) air leak L. chest tube

Bronchial Injury
SGW Chest

**Hemodynamics**
- CVP: 7mmHg
- PAP: 30/16 mmHg
- CO/CI: 5.0/3.6 lpm
- SV: 60 ml
- RV EVDVI: 110
- SVO2: 62%

**Labs**
- H/H: 7.0/23
- INR 1.8
SGW Chest

• PEEP to 12 cm H$_2$O on the injured side

• Warm the patient

• Begin infusion analgesics, anxiolytics, and NMBs
SGW Chest: 30 minutes later

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABG</td>
<td>7.37/39/90, HCO₃: 26/+1, SaO₂: 95%</td>
</tr>
<tr>
<td>CVP</td>
<td>10 mmHg</td>
</tr>
<tr>
<td>PA</td>
<td>35/18 mmHg</td>
</tr>
<tr>
<td>HR</td>
<td>126</td>
</tr>
<tr>
<td>Temp</td>
<td>35 C (core)</td>
</tr>
<tr>
<td>CO/CI</td>
<td>4.0/2.4 lpm</td>
</tr>
<tr>
<td>SV</td>
<td>54 ml</td>
</tr>
<tr>
<td>REDVI</td>
<td>90</td>
</tr>
<tr>
<td>SVO₂</td>
<td>60%</td>
</tr>
<tr>
<td>BP</td>
<td>80/60</td>
</tr>
</tbody>
</table>

**WHATS GOING ON ?**
SGW Chest

• Interventions
  – 2 units of FFP
  – 2 units of PRBCS
SGW Chest

**Hemodynamics**

- **CVP**: 11 mmHg
- **PA**: 35/24 mmHg
- **CO/CI**: 8.5/5.5 lpm
- **SV**: 106 ml
- **RVEDVI**: 130
- **SVO2**: 69%

**Labs**

- **H/H**: 10/23
- **INR**: 1.4

**BP**: 116/70, **HR**: 114, **Temp**: 37.2 C

**ABG**: 7.40, 39, 110, 26/+1, 98%
GSW Chest: 48hrs. later

R: normal

<table>
<thead>
<tr>
<th>Vt: 300 ml</th>
<th>L: Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate: A/C: 16</td>
<td>16</td>
</tr>
<tr>
<td>FiO2: 0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>PEEP: +5</td>
<td>+7</td>
</tr>
<tr>
<td>PIP: 22 cmH\textsubscript{2}O</td>
<td>30 cmH\textsubscript{2}O</td>
</tr>
<tr>
<td>Ppl: 15 cmH\textsubscript{2}O</td>
<td>24 cm H\textsubscript{2}O</td>
</tr>
<tr>
<td>Cs: .050 ml/cm/H\textsubscript{2}O</td>
<td>.040 ml/cm/H\textsubscript{2}O</td>
</tr>
</tbody>
</table>

Trial whole lung ventilation
GSW Chest: Whole lung ventilation

Double lumen tube to one vent.

Mode: PRVC/VC+

Vt: 550 ml

Rate: A/C: 14

FiO2: 0.5

PEEP: +7 cmH₂O

PIP: 28 cmH₂O

Ppl: 20 cm H₂O

Cs: 0.040 ml/cm/H₂O

ABG: 7.38, 39, 106, 24/0, 98%
SGW Chest Summary

• Trached on POD #7

• Pressure support wean

• Decannulated POD # 26

• Discharged to Rehab POD #30
Create safe passage for our patients through the healthcare experience

– Treating the patient for the immediate problems
– Protecting them from complications of injury/illness and the associated treatments
Potential Complications

- Ateletasis
- Pneumonia
- ARDS
- Sepsis
- Volume Overload
- Musculoskeletal
  - Immobility
  - Pressure ulcers
Management

Pain Control
- Epidural
- Blocks
- PCA

Pulmonary Mechanics
- Rib fixation

Pulmonary Toilet
- CLRT
- Positioning
- CPT/IPPV/IS
- Mobilize
- Proning
- Bronchodilators
- Pulmonary Vasodilators

Pharmacology
Epidural Analgesia

Transmission

- Spinothalamic tract neuron
- Substance P
- Opioid receptors
- Nociceptor

Dorsal Horn

Afferent Pain Fiber
Bibliography

Thank You

john.gallagher@uphs.upenn.edu