48 M with PMHx of Bipolar disorder, previous suicide attempts, polysubstance abuse, DM, and HLD presented to ED as Level 1 Trauma code as a pedestrian struck. Patient was seen jumping in front of a car, being flung to the ground and then being run over by a second car. He was GCS 13 on arrival.

- Vitals: 116/62, 99, 98.0, 16
- Airway intact
- Breath sounds bilaterally
- Obvious L anterior chest wall deformity with flail chest and road rash
- Abdomen soft, non tender, non distended
- FAST positive for fluid in Morrison's pouch
- Pelvis stable
CT Chest
CT Chest
Case presentation

- **CT head**: Negative

- **CT facial**: Right orbital fracture

- **CT spine**: Negative

- **CT chest**: Mild left upper lobe and lingular contusions, mild pleural effusion and trace bilateral pneumothoraces <5%. Right 4, 5, 6, 8, 9, 10 rib fractures non-displaced, left 2-6 fractures severely to moderately displaced; L 4th rib abuts the anterior wall of heart, severely displaced clavicular fracture.

- **CTA/P**: Mild liver laceration with mild hematoma.
Hospital Course

- HD #1: Admitted to SICU for pain control and monitoring. Given the patient’s history with substance abuse it was difficult to adequately control his pain and he desaturated to mid 80s and was intubated.

- Noted to have progress drop in H/H from 13 -> 10 and hypotension but stable HR in the 60s and adequate UOP of 50cc/hr; hepatic angiogram performed by IR which was negative.

- HD #2: Patient underwent Thoracotomy with stabilization of left ribs 2-5 via plating and left 6th rib stabilization via sternal wires; ligation of the internal mammary artery. Intraoperatively he was noted to have increasing airway pressures and was difficult to ventilate, a R sided chest tube was placed for presumed pneumothorax and his ventilatory issues resolved.
Hospital Course

- HD # 4: febrile to 102, pan cultured and started on empiric antibiotics (Van c/Aztreonam)
- Repeat CT chest performed to rule out PNA/empyema as patient has worsening respiratory function and noted to have a large L sided pleural effusion that was not drained by the chest tube, a second chest tube was placed on the L side and evacuated 400cc of serosanguinous fluid.
- HD # 6: BAL cultures positive for Klebsiella PNA, continued on antibiotics
- HD #10: Chest tubes pulled
- HD# 12: Patient self extubated
- HD # 14: Patient transferred to inpatient psychiatry ward.
Rib Fractures and the Flail Chest

- Flail chest is defined as 3 or more consecutive rib fractures, that are fractured both anteriorly and posteriorly.

- First described in 1940s along with the rise of the automobile, as it increased in frequency and was termed “steering wheel injury.”
Normal Respiration

Inhalation

RIBS RAISED BY EXTERNAL INTERCOSTAL MUSCLES CONTRACTING

Lung Inflates

Air Enters Lungs

Diaphragm Flattens and Lowers

Exhalation

RIBS LOWERED BY EXTERNAL INTERCOSTAL MUSCLES RELAXING

Lungs Deflate

Air Leaves Lungs

Diaphragm Relaxes and Moves Up
Spirometry

Volume-pressure Curves

- \([P_a - P_i]\) = Wall pressure
- \([P_m - P_i]\) = Mouth pressure
- \([P_w - P_i]\) = Lung pressure
- Total compliance: 1 ml Pa⁻¹
- Thoracic compliance: 2 ml Pa⁻¹
- Lung compliance: 2 ml Pa⁻¹

Normal lung volumes in a 70 kg individual

- FRC, functional residual capacity (2.5 litres)
- RV, residual volume (1.25–2.0 litres)
- TV, tidal volume (0.5–0.6 litres)
- ERV, expiratory reserve volume (1.25 litres)
- VC, vital capacity (3.5–5.5 litres)
- TLC, total lung capacity (6 litres)

Healthy person: 1/1 = \(1/3 + 1/2\)

Fig. 13.3
KMc
Flow volume Loop Analysis

MFVL = Maximal Flow Volume Loop
extFVL = Exercise Tidal Flow Volume Loop
VT = Tidal Volume
EELV = End expiratory Lung Volume
EILV = End Inspiratory Lung Volume
VT = Tidal volumes
ERV = expiratory reserve volume
IRV = Inspiratory reserve volume
IC = Inspiratory capacity
Flow-Volume Loops

Flow volume loops provide a graphical illustration of a patient's spirometric efforts. Flow is plotted against volume to display a continuous loop from inspiration to expiration. The overall shape of the flow volume loop is important in interpreting spirometric results.
What happens in Flail Chest?
What happens in Flail Chest?
“The disturbances of respiratory mechanics created by paradoxical respiration are easily controlled when there is no lesion of the lung. When the lung is injured the main problem is respiratory insufficiency created by temporary compromise of lung function” Garzon et al
Treatments

- Controversial; patient centered as three separate issues are affected. Pain control/Analgesia is first line. If ineffective then more invasive measures used.
- Divided into two classes internal support and external support
  - Internal support: Mechanical positive pressure ventilation
  - External support: Non operative vs Operative
When do we fix??

Simplified guideline for rib fracture repair

- **Flail chest resulting in prolonged ventilation**
  - Failure to wean ventilator after 7 days of incompetent chest wall

- **Pain and disability associated with fracture movement**
  - Minimal or no extra-thoracic injury and has failed a 7-10 day trial of inpatient pain control

- **Significant chest wall deformity**
  - Treatment because of severity of chest wall deformity regardless of pulmonary status

- **Rib fracture non-union**
  - CT scan evidence of fracture non-union (>2 months after injury)

Granetzny et al. “45% of pts who underwent surgical fixation required ventilator support for an average of 2 days, while those who underwent conservative therapy averaged 12 days.”

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Blood gas analysis in 40 patients with traumatic flail chest</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Before management Mean±S.D.</td>
</tr>
<tr>
<td></td>
<td>pO₂</td>
</tr>
<tr>
<td>Conservative group</td>
<td>63.6±9.1</td>
</tr>
<tr>
<td>Surgical group</td>
<td>56.2±9.2</td>
</tr>
</tbody>
</table>

Partial pressure of oxygen (pO₂), partial pressure of carbon dioxide (pCO₂). Not significant (n.s.)

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Post-management data in 40 patients with traumatic flail chest</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Conservative group (N=20)</td>
</tr>
<tr>
<td>Post management data</td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>7 (35%)</td>
</tr>
<tr>
<td>Number of patients (%)</td>
<td></td>
</tr>
<tr>
<td>Mean duration of mechanical ventilation (days)</td>
<td>12</td>
</tr>
<tr>
<td>Mean ICU stay (days)</td>
<td>14.6</td>
</tr>
<tr>
<td>Mean hospital stay (days)</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Not significant (n.s.)
Marasco et al. “Patients in the operative fixation group had significantly shorter ICU stays, with shorter ventilator requirements. No differences were noted in spirometry or quality of life at 3 or 6 months”

This study demonstrated a cost savings of $14,443 per patient who underwent rib stabilization.
The sum of the four primary lung volumes (tidal volume, inspiratory reserve volume, expiratory reserve volume, and residual volume) equals

- A: Functional residual capacity
- B: Vital Capacity
- C: Total Lung Capacity
- D: Maximum Ventilatory Volume
Questions??

- All the lung volumes can be measured by spirometry except
- A: Tidal Volume
- B: Inspiratory Reserve Volume
- C: Expiratory Reserve Volume
- D: Residual Volume
Questions??

- Restrictive lung disease is best defined by which of the following parameters?
  - A: reduced diffusion capacity
  - B: reduced FEV1
  - C: reduced FVC
  - D: reduced TLC
The definition of obstruction of PFTs is best defined by:

- **A**: an FEV1/FVC that is less than 70 to 75% of predicted
- **B**: an FVC that is less than 75% predicted
- **C**: a maximal mid-expiratory flow that is less than 70 to 75% predicted
- **D**: total lung capacity that is less than 70 to 75% of predicted
References

- Bemelman, et al. Historic overview of treatment techniques for rib fractures and flail chest; European Journal of Trauma and Emergency Surgery; 2010: Vol 36
- Marasco, et al. Prospective Randomized Controlled Trial of Operative Rib Fixation in Traumatic Flail Chest; American College of Surgeons: 2013: Vol 216, No 5