Rib Fractures and Traumatic Pneumothorax: Physiology and Management

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Objectives

• AT the end of this talk you should be able to
  – Describe the physiology of an effective cough
  – Recognize how rib fractures impair sputum clearance and promote atelectasis
  – Describe a “classic” 3-bottle pleural drainage system as well as the more modern drainage kits
  – Discuss standard management of traumatic pneumothorax
Outline

• Pulmonary physiology review
  – Pressure changes with normal breathing
  – Forced expiratory flow & Peak expiratory flow
  – Cough

• Rib fractures & Flail
  – Impact on cough and development of atelectasis
  – Management

• Pneumothorax
  – Diagnosis
  – Pleural drainage systems
  – Management
Review of some Pulmonary Physiology

• Lungs have an inward elastic recoil
  – Given their druthers, the lungs would collapse into a small relatively airless organ

• The chest wall has outward elastic recoil
  – Without the lung “pulling” the chest in, our chest would be at a higher resting volume

• The balance between lung and chest wall elastic recoils determines resting lung volume (FRC)
  – “resting” lung volume is that point where the inward lung elastic recoil equals the outward elastic recoil of the lung
Normal Breathing

Inspiration:
- Diaphragm contracts downward
- Pressure (P) decreases
- Volume (V) increases
- 760 mmHg
- 757 mmHg

Expiration:
- Diaphragm relaxes upward
- Pressure (P) increases
- Volume (V) decreases
- 760 mmHg
- 763 mmHg
• If lung elastic recoil is reduced, thoracic volume will go UP (less force pulling the rib cage in)
  – Emphysema with destruction of alveolar sacs
  – Pneumothorax (sort of)
• If lung elastic recoil increases, thoracic volume will go DOWN (more force pulling the rib cage in)
  – Pulmonary fibrosis
  – Atelectasis
Forced Expiratory Flow

- Limited by dynamic airway compression: No matter how hard we squeeze, there is a limit to how fast the air will come out.
- Peak flow is a function of lung volume: Higher starting lung volume → higher peak flow due to greater lung elastic recoil (“spring” analogy).
Normal Peak Expiratory Flow

Normal values for peak expiratory flow (PEF)
EN 13826 or EU scale

Men
Women

PEF (L/min)

Height
- 190 cm or 75"
- 183 cm or 72"
- 175 cm or 69"
- 167 cm or 66"
- 160 cm or 63"
- 152 cm or 60"

Age (years)
Cough

• Essential, normal protective reflex
• Three phases:
  – Inhalation
  – Compressive phase
  – Expulsive phase
• An effective cough compresses major airways that are not normally compressed during exhalation
• This leads to increased air flow above the maximum peak flow that can be generated with standard force exhalation
How we Cough

• Take a deep breath
  – Takes advantage of lung elastic recoil (spring analogy)
• Close your glottis
• Contract muscles of expiration (mostly abdominal) to build up intrathoracic pressure
• Open glottis and . . .
  Continue to contract muscles of expiration during the entire cough
Cough with rib fractures

• Take a deep breath: OUCH!
  – Small Vc; less elastic recoil
• Close glottis
• Contract abdominal muscles: OUCH!
• Open glottis
• Continue to contract abdominal muscles: OUCH!
Why does an Impaired Cough Matter?

- Anatomic dead space of the lung: about 150 ml in males
- Impaired cough → Inability to cough up sputum → airway plugging → atelectasis
- Atelectasis → decreased pulmonary compliance
- Decreased pulmonary compliance → lower Vc
- Lower Vc → less effective cough
- Repeat

#AllCoughsMatter
Sputum Volume in Chronic Bronchitis

• 48 hospitalized patients recovering from acute exacerbation of chronic bronchitis
• Sputum varied from 10 ml to > 60 ml/24 hours
• Over half produced > 20 ml/24 hours

Ashcroft. British M Journal 1965; 288-90
Flail

• Multiple (usually 3 or more) ribs, each fractured in 2 locations, leading to a segment of chest wall that moves paradoxically with breathing

• Normally as intrathoracic pressure decreases during inspiration the chest wall moves OUT

• The flail segment will paradoxically move INWARD, limiting lung expansion
Significance of Flail

• Pain (as with all multiple rib fractures) → impaired cough

• Marker of underlying lung injury (commonly associated with pulmonary contusion) → stiffer lung, harder to take big breath

• Impairment in Vc directly due to paradoxical chest wall movement
  – Virtually no way to separate the effects of pain from the effects of the flail itself
Management of Rib Fractures

• Who to admit/observe?
  – Multiple fxs (3 or more)
  – Older patients
  – Underlying obstructive lung disease
  – Chronic bronchitis/bronchiectasis

• Pain management: a lecture on its own

• Airway clearance: another lecture

• Role for surgery?
  – Yes → but no good studies
When to operate on rib fractures and flail chest?

• Generally poor studies
  – Largely retrospective
  – Usually non-randomized
  – Often unclear why some patients operated on while others not
  – Usually small numbers of patients
  – Usually single center reports
When to Operate?

• No good answer yet
• Still awaiting properly conducted, adequately sized/stratified randomized studies looking at acute and later relevant outcomes
• In mean time, not unreasonable to surgically stabilize fractures in patients with respiratory failure in whom the rib fractures or flail per se are felt to be major contributors to ongoing management challenges
Traumatic Pneumothorax

• Foreign body penetration
  – Bullet, knife, impalings
• Rib fracture with pulmonary laceration
• Chest compression with transiently increased intrathoracic pressure
• Shear during deceleration
• Occasional association with bronchial fracture
Identification

• Plain chest radiograph
• CT
• Ultrasound
Chest Radiograph

- Sensitivity decreases in supine patients
- Air rises: leads to different collection of findings
- Deep sulcus sign
Chest CT

• Gold standard
• “Too” sensitive: finds tiny pneumothoraces that need no therapy
Ultrasound

• Quick
• User dependent but easy to learn
• More sensitive than supine chest radiographs
• Somewhat less sensitive than CT scan
  – Operator dependent
  – How many interspaces to image?
  – Interference with subcutaneous air, bandages
• Poor data on quantification of size
Management

• Observation
  – Appropriate for large majority of blunt force trauma patients with small asymptomatic pneumothoraces

• Tube thoracostomy
Summary

• Baseline lung and patient characteristics (age, muscle strength, gender, underlying structural lung disease) determine peak expiratory flow and peak cough flow

• Cough is important in airway clearance, particularly in conditions with increased sputum production

• Rib fractures, via a variety of mechanisms, lead to poor cough, poor clearance, atelectasis, pneumonia, and respiratory failure
• Rib fracture management is controversial, although the basics include admission for high risk patients, pain control, pulmonary toilet, and surgical stabilization is select patients

• Pneumothorax can be detected by CXR, CT, or US; each has its role. The use of US is rapidly evolving and is being increasingly integrated into FAST exams but hard data are lagging
• Pleural collection systems are all based on the classic “3 bottle” system, but now are easier to use, with newer dry suction systems being available
Questions & Comments?