Managing Chest Drainage

What you will learn

• Anatomy & physiology of the chest relating to chest drainage
• Mechanics of breathing
• Conditions requiring pleural chest drainage
• Chest drain basics (3 bottle systems)
• Disposable chest drains

Thoracic cavity

• This space is defined by:
  – Sternum anterior
  – Thoracic vertebrae posterior
  – Ribs lateral
  – Diaphragm inferior
• “Chest wall” composed of ribs, sternum, thoracic vertebrae interlaced with intercostal muscle
• The diaphragm is the “floor” of the thoracic cavity

Breathing: inspiration

• Brain signals the phrenic nerve
• Phrenic nerve stimulates the diaphragm (muscle) to contract
• When diaphragm contracts, it moves down, making the thoracic cavity larger
  (keep this in mind as we discuss physics)

How does air move into the lungs?

• Physics is phun!
  – If you understand the principles of gas flow, you will understand chest drainage
  – As pressures change, air moves
**Physics of gases**

- Air is made up of gas molecules
- Gas molecules in a container collide and create a force
- **Pressure** is the amount of the force created by the gas molecules moving and colliding

**Physics of gases: Boyle’s law**

- When the volume of a container increases, the pressure decreases
- When the volume of a container decreases, the pressure increases
- If you’re trying to squeeze as many people in a car as possible, they will be under much higher pressure in a VW Beetle than the same number of people would be in a minivan

**Physics of Gases**

If two areas of different pressure communicate, gas will move from the area of higher pressure to the area of lower pressure

This movement of air causes wind when a high pressure system is near a low pressure system in the atmosphere

**Breathing: inspiration**

- When the diaphragm contracts, it moves down, increasing the volume of the thoracic cavity
  - When the **volume increases**, the **pressure** inside decreases
- Air moves from an area of higher pressure, the atmosphere, to an area of lower pressure, the lungs
- Pressure within the lungs is called intrapulmonary pressure
Breathing: exhalation

- Exhalation occurs when the phrenic nerve stimulus stops
- The diaphragm relaxes and moves up in the chest
- This reduces the volume of the thoracic cavity
- When volume decreases, intrapulmonary pressure increases
- Air flows out of the lungs to the lower atmospheric pressure

Breathing

- Remember, this is normally an unconscious process
- Lungs naturally recoil, so exhalation restores the lungs to their resting position
- However, in respiratory distress, particularly with airway obstruction, exhalation can create increased work of breathing as the abdominal muscles try to force air out of the lungs

Pleural anatomy

Lungs are surrounded by thin tissue called the pleura, a continuous membrane that folds over itself
- Parietal pleura lines the chest wall
- Visceral pleura covers the lung (sometimes called the pulmonary pleura)

Pleural anatomy

Normally, the two membranes are separated only by the lubricating pleural fluid
- Fluid reduces friction, allowing the pleura to slide easily during breathing

Normal Pleural Fluid Quantity:
Approx. 25mL per lung

Pleural physiology

- The area between the pleurae is called the pleural space (sometimes referred to as “potential space”)
- Normally, vacuum (negative pressure) in the pleural space keeps the two pleurae together and allows the lung to expand and contract
- During inspiration, the intrapleural pressure is approximately -8cmH₂O (below atmosphere)
- During exhalation, intrapleural pressure is approximately -4cmH₂O

Pressures

- Intrapulmonary pressure (the pressure in the lung) rises and falls with breathing
- Equalizes to the atmospheric pressure at end-exhalation (defined as 0 cmH₂O because other pressures are compared to it as a baseline)
- Intrapleural pressure also fluctuates with breathing ~ 4 cmH₂O less than the intrapulmonary pressure
- The pressure difference of 4 cmH₂O across the alveolar wall creates the force that keeps the stretched lungs adherent to the chest wall
When pressures are disrupted

If air or fluid enters the pleural space between the parietal and visceral pleura, the -4cmH₂O pressure gradient that normally keeps the lung against the chest wall disappears and the lung collapses.

Intrapleural pressure: -8cmH₂O
Intrapulmonary pressure: -4cmH₂O

Conditions requiring chest drainage

- Blood in the pleural space is a hemothorax
- Transudate or exudate in the pleural space is a pleural effusion

Conditions requiring chest drainage: pneumothorax

- Pneumothorax
  - Occurs when there is an opening on the surface of the lung or in the airways, in the chest wall — or both.
  - The opening allows air to enter the pleural space between the pleurae, creating an actual space.

Conditions requiring chest drainage: open pneumothorax

- Open pneumothorax
  - Occuring in the chest wall (with or without lung puncture)
  - Allows atmospheric air to enter the pleural space
  - Penetrating trauma: stab, gunshot, impalement
  - Surgery

Photo courtesy trauma.org
**Conditions requiring chest drainage:**

**Closed pneumothorax**
- Chest wall is intact
- Rupture of the lung and visceral pleura (or airway) allows air into the pleural space

**Open pneumothorax**
- An open pneumothorax is also called a “sucking chest wound”
- With the pressure changes in the chest that normally occur with breathing, air moves in and out of the chest through the opening in the chest wall
- Looks bad and sounds worse, but the opening acts as a vent so pressure from trapped air cannot build up in the chest

**Tension pneumothorax**
- A tension pneumothorax can kill
- Chest wall is intact
- Air enters the pleural space from the lung or airway, and it has no way to leave
- There is no vent to the atmosphere as there is in an open pneumothorax
- Most dangerous when patient is receiving positive pressure ventilation in which air is forced into the chest under pressure

**Mediastinal shift**
- Mediastinal shift occurs when the pressure gets so high that it pushes the heart and great vessels into the unaffected side of the chest
- These structures are compressed from external pressure and cannot expand to accept blood flow

**In a closed pneumothorax**, a patient who is breathing spontaneously can have an equilibration of pressures across the collapsed lung
- The patient will have symptoms, but this is not life-threatening

**Tension pneumothorax occurs when a closed pneumothorax creates positive pressure in the pleural space that continues to build**
- That pressure is then transmitted to the mediastinum (heart and great vessels)
Conditions requiring chest drainage: mediastinal shift
- Mediastinal shift can quickly lead to cardiovascular collapse
- The vena cava and the right side of the heart cannot accept venous return
- With no venous return, there is no cardiac output
- No cardiac output = not able to sustain life

Conditions requiring chest drainage: tension pneumothorax
- When the pressure is external, CPR will not help – the heart will still not accept venous return
- Immediate, live-saving treatment is placing a needle to relieve pressure followed by chest tube

Conditions requiring chest drainage: hemothorax
- Hemothorax occurs after thoracic surgery and many traumatic injuries
- As with pneumothorax, the negative pressure between the pleurae is disrupted, and the lung will collapse to some degree, depending on the amount of blood
- The risk of mediastinal shift is insignificant, as the amount of blood needed to cause the shift would result in a life-threatening intravascular loss

Conditions requiring chest drainage: pleural effusion
- Fluid in the pleural space is pleural effusion
  - Transudate is a clear fluid that collects in the pleural space when there are fluid shifts in the body from conditions such as CHF, malnutrition, renal and liver failure
  - Exudate is a cloudy fluid with cells and proteins that collects when the pleurae are affected by malignancy or diseases such as tuberculosis and pneumonia

Treatment for pleural conditions
1. Remove fluid & air as promptly as possible
2. Prevent drained air & fluid from returning to the pleural space
3. Restore negative pressure in the pleural space to re-expand the lung
Thoracostomy creates an opening in the chest wall through which a chest tube (also called thoracic catheter) is placed, which allows air and fluid to flow out of the chest.

Also called "thoracic catheters"
- Different sizes
  - From infants to adults
  - Small for air, larger for fluid
- Different configurations
  - Curved or straight
- Types of plastic
  - PVC
  - Silicone
- Coated/Non-Coated
  - Heparin
  - Decrease friction

At the end of the procedure, the surgeon makes a stab wound in the chest wall through which the chest tube is placed into the pleural space.

Chest tube is attached to a drainage device
- Allows air and fluid to leave the chest
- Contains a one-way valve to prevent air & fluid returning to the chest
- Designed so that the device is below the level of the chest tube for gravity drainage
How does a chest drainage system work?

It's all about bottles and straws

- Most basic concept
- Straw attached to chest tube from patient is placed under 2cm of fluid (water seal)
- Just like a straw in a drink, air can push through the straw, but air can’t be drawn back up the straw

This system works if only air is leaving the chest
- If fluid is draining, it will add to the fluid in the water seal, and increase the depth
- As the depth increases, it becomes harder for the air to push through a higher level of water, and could result in air staying in the chest

The two-bottle system is the key for chest drainage
- A place for drainage to collect
- A one-way valve that prevents air or fluid from returning to the chest

Many years ago, it was believed that suction was always required to pull air and fluid out of the pleural space and pull the lung up against the parietal pleura
- However, recent research has shown that suction may actually prolong air leaks from the lung by pulling air through the opening that would otherwise close on its own
- If suction is required, a third bottle is added
**Restore negative pressure in the pleural space**

- **The straw submerged in the suction control bottle** (typically to 20 cm H₂O) limits the amount of negative pressure that can be applied to the pleural space – in this case -20 cm H₂O.
- The submerged straw is open at the top.
- As the vacuum source is increased, once bubbling begins in this bottle, it means atmospheric pressure is being drawn in to limit the suction level.

**The depth of the water in the suction bottle determines the amount of negative pressure that can be transmitted to the chest, NOT the reading on the vacuum regulator.**

- There is no research to support this number of -20 cm H₂O, just convention.
- Higher negative pressure can increase the flow rate out of the chest, but it can also damage tissue.

**How a chest drainage system works**

- **Expiratory positive pressure** from the patient helps push air and fluid out of the chest (cough, Valsalva).
- **Gravity** helps fluid drainage as long as the chest drainage system is below the level of the chest.
- **Suction** can improve the speed at which air and fluid are pulled from the chest.

**From bottles to a box**

- The bottle system worked, but it was bulky at the bedside and with 16 pieces and 17 connections, it was difficult to set up correctly while maintaining sterility of all of the parts.
- In 1967, a one-piece, disposable plastic box was introduced.
- The box did everything the bottles did – and more.
From bottles to a box

Collection bottle
Water seal bottle
Suction control bottle

From boxes to bedside

At the bedside

- Keep drain below the chest for gravity drainage
- This will cause a pressure gradient with relatively higher pressure in the chest
- Fluid, like air, moves from an area of higher pressure to an area of lower pressure
- Same principle as raising an IV bottle to increase flow rate

Monitoring intrathoracic pressure

- The water seal chamber and suction control chamber provide intrathoracic pressure monitoring
- Gravity drainage without suction: Level of water in the water seal chamber = intrathoracic pressure (chamber is calibrated manometer)
  - Slow, gradual rise in water level over time means more negative pressure in pleural space and signals healing
  - Goal is to return to -8cmH₂O
- With suction: Level of water in suction control + level of water in water seal chamber = intrathoracic pressure

Monitoring air leak

- Water seal is a window into the pleural space
- Not only for pressure
- If air is leaving the chest, bubbling will be seen here
- Air leak meter (1-5) provides a way to "measure" the leak and monitor over time – getting better or worse?

Setting up the drain

- Follow the manufacturer’s instructions for adding water to the 2cm level in the water seal chamber, and to the 20cm level in the suction control chamber (unless a different level is ordered)
- Connect 6’ patient tube to thoracic catheter
- Connect the drain to vacuum, and slowly increase vacuum until gentle bubbling appears in the suction control chamber
Setting up suction

• You don’t need to boil spaghetti!
• Vigorous bubbling is loud and disturbing to most patients
• Will also cause rapid evaporation in the chamber, which will lower suction level
• Too much bubbling is not needed clinically in 98% of patients – more is not better
• If too much, turn down vacuum source until bubbles go away, then slowly increase until they reappear, then stop

Disposable chest drains

• Collection chamber
  – Fluids drain directly into chamber, calibrated in mL fluid, write-on surface to note level and time
• Water seal
  – One way valve, U-tube design, can monitor air leaks & changes in intrathoracic pressure
• Suction control chamber
  – U-tube, narrow arm is the atmospheric vent, large arm is the fluid reservoir, system is regulated, easy to control negative pressure