Thoracic Ultrasound

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Objectives

• Introduction to thoracic ultrasound
• Pneumothorax
• Pleural effusion
• Pulmonary Embolism
• Pulmonary Hypertension
Solid Organ versus Lung Ultrasound

• Leap of faith since it is artifact driven

• Eventually the artifacts become a language just like an EKG
Indications for Thoracic Ultrasound

1. Detection of pleural fluid when the plain CXR shows a “white out”
2. Detection of a PTX
3. Guidance for thoracentesis and chest tube placement
4. COPD versus CHF
Scanning Strategy

• The transducer is oriented to scan between the ribs, as ribs block transmission of ultrasound.

• This orientation yields an image where the adjacent rib shadows appear on either side of the image on the screen (batwing sign).

The ribs are identified by their characteristic posterior shadowing, and below two contiguous ribs, a hyperechoic line can be seen. This line, denoted as the "pleural line," represents the parietal and visceral pleural interface.
Ultrasound Terminology

- Ultrasound waves are formed in the transducer.
- Some sound waves pass through various interfaces and some are reflected.
- Sound waves that are reflected back to the probe are detected as echoes and form the image that we see on the screen.
- When dealing with ultrasound waves, the descriptive terms are based in “echogenicity”.

- **Echogenicity**: is the ability to reflect ultrasound waves and produce echoes.
- Each tissue type has a particular echogenicity in its normal state:
  - **Hyperechoic** (white)
    - Pleura
  - **Hypoechoic** (gray)
    - Lung consolidation, exudative effusion
  - **Anechoic** (black)
    - Transudative effusion
Pulmonary Ultrasound

• **Linear probe:**
  • Higher frequencies (5 to 13 MHz) provides better resolution and less penetration
  • Better for imaging superficial structures and vessels
  • Also called a vascular probe
  • Typically generate rectangular images on the screen
  • Used for PNX evaluation

• **Phased array:**
  • Lower frequencies (2 to 8 MHz)
  • Generate sector or “pie-shaped” images, narrower in the near field and wider in the far field
  • Ideal for echocardiography and pleural effusions
BLUE Protocol

- **BLUE:** “Bedside Lung Ultrasound in Emergency”
  - Upper BLUE point: upper lobes
  - Lower BLUE point: middle lobe / lingula
  - PLAPS point: lower lobes
    - Is the lowest point in the lung so this is where you find pleural fluid

- **PLAPS:** “posterior-lateral alveolar pleural syndrome”
  - Posterior-lateral: around the back
  - Alveolar syndrome: consolidation
  - Pleural syndrome: pleural effusion

BLUE Protocol

• **3 items were assessed:**
  1. Artifacts
     • Horizontal A lines
     • Vertical B lines
  2. Lung sliding
  3. Alveolar consolidation and/or pleural effusion
• A tool for acute respiratory failure which provides a **90.5%** accuracy of diagnosis and takes only a few minutes
• It should be done as part of the physical examination after the history and before other investigations

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Pneumothorax
Pleural and PNX

• Lots of evidence to **exclude** PNX but not to diagnose

• **2D mode** for the sliding lung sign using the linear probe
  o Lung sliding is normal (no PNX)
  o B-Lines are vertical lines that can either be normal variant or in the right clinical situation mean volume overload

• **M-Mode** (motion mode) to look for:
  o “Sea shore” sign (no PNX)
  o “Bar code” or “Stratosphere” (PNX)
  o “Lung point”: meaning normal & abnormal findings on M-Mode
    • This is consider almost definite for PNX
Lung Sliding (ants on a string)

- Created by movement of the lung relative to the chest wall during respiration
- Hyperechoic line moving horizontally along the pleural line is an indirect sign indicating adherence of the visceral pleura to the parietal pleura
- When air separates the 2 pleural layers as in a PNX, the movement disappears
- Disappearance of lung sliding in an area where it was previously identified is a strong indicator of a PNX
Beyond the Pearls: Lung Pulse

Lung pulse is the equivalent to lung sliding when the patient holds their breath.
A-Lines

- A lines are horizontal lines \textbf{parallel} to pleural line, with same bright echogenic feature
- If there are A lines \textbf{without} of lung sliding this can represent pneumothorax
- If A lines presents \textbf{with} lung sliding this could be asthma or COPD
A-Lines

- Seen in normal lungs or in pneumothorax
- **Absence** of A-lines implies something has change in the lung replacing the air with substances that transmit sound waves
  - Examples: Blood, interstitial or alveolar edema, infection, contusion and tumor
- Remember: **A = Air = Artifact**
**B-Lines**

- **B line** is a **vertical line** that arises from the pleural line and continues to the edge of the screen (Fig. 2) B line will **rule out pneumothorax**

- 2 types of B- lines:
  - 7mm spacing
    - Septal thickening, Kerly B
  - 3 mm spacing
    - Alveoli spacing

- **Comet tails** (Fig. 1) are B-lines that represent sliding of the pleura

**E- lines**: Vertical lines extending from the areas of subcutaneous emphysema deep into the chest

**Z- lines**: Vertical lines that fade quickly and do not move with respiration
Abnormal when B-lines replaces A-lines this is seen when “fluid” replaces “air”
M-Mode

M-mode allows documentation of lung sliding with a single image. Superficial soft tissue/muscle does not move much during respirations, and will yield flat lines on M-mode (top half of images below). Normal lung sliding creates a grainy M-mode appearance (left image, bottom). This is referred to as “waves on a beach,” where the smooth soft tissue lines (top half) meet the rough lung lines (bottom half) at the bright white pleural line (center). With pneumothorax, lung sliding is absent—flat lines will be seen above and below the pleura.

“seashore” or “waves on the beach”

“barcode” or “stratosphere”
No Lung Sliding Video
No Lung Sliding Video
Lung Point

- The **most specific sign** for PNX using ultrasound
- Using **M-mode**, the lung point will give the appearance of alternating normal lung and pneumothorax
- The classic normal “**waves on the beach**” appearance will alternate with “**stratosphere**” or “**barcode**” signs
Pleural and PNX

• The 3 steps for US exam for PNX:
  1. Start at the anterior chest wall, mid-clavicular line
  2. Start at 5 cm depth with the linear probe
  3. Start perpendicular to the ribs
Pleural and PNX

• No lung sliding but not a PNX, what else could it be?
  1. ARDS
  2. Consolidation
  3. Apnea
  4. Atelectasis
  5. Pleurodesis
Supine patient with ? pneumothorax

B-lines and/or Lung slide? Yes

Free-flowing PTX excluded (loculated PTX elsewhere is still possible, but uncommon and less significant)

No

M-Mode

Seashore Sign

Barcode (aka, stratosphere) Sign

Lung point? (slide probe from anterior to posterior thorax looking for lung-PTX interface)

(+ ) lung point

Definite PTX

Lung point located anteriorly

Probably smaller PTX

Proven smaller PTX

(- ) lung point

Probable PTX

Lung point located posteriorly

Probably larger PTX

Unstable patient

Consider chest tube based on clinical correlation

Stable patient

STAT CXR
Question
Objectives

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• **Pleural effusion**
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Pleural Effusion
Identification of Pleural Fluid

• If CXR available, it should be reviewed before the ultrasound guided procedure to confirm the expected site, size, and likelihood of loculations.

• Echogenicity of thoracic structures is determined relative to the liver (hepatization of the lung).
Characteristics Features of a Pleural Effusion

- Pleural fluid usually appears as an anechoic (black), or hypoechoic compared to the liver.
- 3 sonographic criteria must be satisfied to ensure the presence of a pleural effusion:
  1. Anechoic free space within the thoracic cavity.
  2. Anatomic boundaries that surround the effusion:
     - Chest wall
     - Diaphragm
     - Surface of the lung
  3. Dynamic characteristics that are typical of pleural fluid:
     - Diaphragmatic movement
     - Lung movement (jelly fish and curtain sign)
     - Movement of echogenic material within the fluid such as septations and cellular debris (plankton sign)
Characteristics Features of a Pleural Effusion

• Unlike intra-abdominal fluid, a pleural effusion is **not deformable** with force application to the transducer on account of the rigidity of thoracic cage.
Pleural Effusion Video

This video shows the typical anatomic boundaries that surround a hypoechoic pleural effusion. The 3.5 MHz transducer is in longitudinal orientation and placed perpendicular to the chest.
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Atypical Appearances of Pleural Effusion

- Examples:
  - Massive obesity and chest wall edema
  - Complex loculated effusions may be hyperechoic and be located in a nondependent part of the thorax
  - Pleural or diaphragmatic thickening or nodularity is suggestive of a malignant pleural effusion
  - The presence of air and fluid together (hydro pneumothorax)
Compared to normal lung, consolidation on ultrasound has a relatively hypoechoic heterogeneous echo texture. Because consolidation appears isoechoic with the liver it has been referred to as lung “hepatization”
Large Pleural Effusion

This video shows a large pleural effusion and atelectatic lung. The 3.5 MHz transducer is in longitudinal orientation and placed perpendicular to the chest wall to scan through the 6th intercostal space in the right mid-axillary line.
This video shows a **multiseptated** pleural effusion. This pattern is consistent with a complex parapneumonic effusion or empyema that will require fibrinolytic treatment or surgical drainage.
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Jelly Fish Sign

Dynamic changes of a flapping lung
The curtain sign refers to the phenomenon of *aerated lung* sweeping down during inspiration and *obscuring the diaphragm*.
Plankton (Hematocrit) Sign

Hemothorax and empyema may appear as a dense homogeneous fluid (partially clotted blood) and in some cases a hematocrit sign can be appreciated.
Patient positioning for the posterior thoracentesis approach. Note that the patient should be sitting forward over a support. The location of needle placement is best determined by using ultrasound.
Positioning for Thoracentesis

Patient positioning for the lateral thoracentesis approach. Note that the patient should be lying supine with the arm extended and the head of the bed elevated. The location of needle placement is best determined by using ultrasound.
Positioning for Thoracentesis

Needle trajectory should be positioned above the rib. Note that the neurovascular bundle is located inferior to the rib and must be avoided during the thoracentesis procedure.
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Ways to Evaluate Right Ventricular Function

• Commonly used methods for calculating diameters, areas, and volumes of the LV are difficult to implement for the right ventricle and are typically not performed.
• Ways to evaluate global RV function:
  1. RV fractional area of change
  2. TAPSE (tricuspid annular plane systolic excursion)
  3. RV outflow tract-shortening fraction (RVOT-SF)
  4. “Eye balling”
Right Ventricular Fractional Area Change (RVFAC)

- Represents a “surrogate” measurement of RV ejection fraction and is expressed as a % change in the RV chamber area from end-diastole to end-systole, rather than change in volume
- Measured in 2D mode apical 4 chamber view
Right Ventricular Fractional Area Change (RVFAC)

RVFAC expresses the percentage change in RV area between end-diastole and end-systole. It is obtained from a four-chamber view where the RV end-diastolic (RV - EDA) and end-systolic areas (RV - ESA) are measured. RV-FAC is calculated as follows: RV FAC (%) = (RV EDA – RV ESA)/RV EDA x 100.
Tricuspid Annular Plane Systolic Excursion (TAPSE)

- TAPSE can be assessed with the 4 chamber apical view using M-mode, measuring the distance of tricuspid annular movement between end-diastole to end-systole on the lateral RV wall.
- Normally >2.0 cm, abnormal is < 1.5 cm.
Right Ventricular Outflow Tract Shortening Fraction (RVOT-SF)

RVOT-SF is obtained from a parasternal short-axis view at the base of the heart where the end-diastolic RV outflow tract diameter (EDRVOTD) and end-systolic RVOT diameter (ESRVOTD) can be measured and the shortening fraction is calculated using the formula: $\text{RVOT-SF (\%) } = \frac{(\text{EDRVOTD} - \text{ESRVOTD})}{\text{EDRVOTD}}$
Parasternal Short Axis (Ao:PA) View on Echocardiogram For Shortening Fraction
Pulmonary Embolism

- Echo is **NOT** a diagnostic tool
- “McConnell’s sign”: for ACUTE PE (not for chronic), can also be seen in RV infarction
- The findings on echo are:
  1. RV lateral wall akinesis
  2. Apical sparing
- 77% Sensitive and 94% Specific in his one study, but has never been duplicated
- McConnell’s sign needs a high pre-test probability / suspicion
- In chronic PE can get RV hypertrophy

"Regional right ventricular dysfunction detected by echocardiography in acute pulmonary embolism". *Am. J. Cardiol.* 78 (4): 469–73
DVT Evaluation

- Focus only on the femoral and popliteal veins
- This is based on evidence that 2 points is good as whole leg exam
- The 4 things to diagnose DVT
  1. Visual first
     - Do not compress if you see the clot, there is a theory that one might dislodge the clot
  2. Compress
  3. Doppler flow
  4. Augmentation
     - “Squeeze the calf”
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Estimation of Pulmonary Artery Systolic Pressure

- **Bernoulli equation**: $4 \times (TRV)^2 + RA\ pressure$
  - Velocity is a surrogate for flow
  - Tricuspid regurgitation estimates estimate PA systolic pressure based on the RVSP
  - The velocity estimates the **CHANGE** in pressure between two points, therefore you need a reference
    - Meaning that you need an accurate RA pressure to estimate the PA systolic pressure, but the problem is getting that accurate RA pressure
    - It is easy if a CVP is placed

- A systolic pressure of **40 mm Hg** typically implies a mean pressure of more than **25 mm Hg**
Estimation of Pulmonary Artery Systolic Pressure

- Assessment of pulmonary artery systolic pressure (PASP) can be carried out by measuring maximal tricuspid regurgitation velocity with Doppler and applying the modified Bernoulli equation to convert this value into pressure values.
- Estimated right atrial pressure (RAP) must be added to this obtained value.
Bernoulli Equation

• Remember that all pressures that are measured in the body are RELATIVE to atmospheric pressure. This is why we “Zero Out” before getting pressure measurements
  • Example: A CVP of 5 means, 5 mmHg above atmospheric pressure
  • There are 4 pressure differences we take into account when estimating the PA pressure
    • Diff between ATM and Superior Vena Cava: (CVP)
    • Diff between the SVC and RA: (which is zero)
    • Diff between RA and RV: (Bernoulli equation)
    • Diff between the RV and the PA: (which is zero)
Question

• CVP = 12 TR velocity = 3 What is the PA systolic pressure?
Answer

• Answer: 48
  • $4 \times (TRV)^2 + RA$ pressure
  • Remember for PA systolic pressure you NEED RA pressure
Summary of Ultrasound Signs

• Sliding lung / Lung point
• Horizontal A-Lines
  o Air
  o Non-parenchymal lung disease
  o COPD
  o PAOP < 13 mmHg with 90% specificity
• Vertical B-lines
  o Reflects fluid in the interlobular septum
  o 3 or more B-lines is pathologic
  o B-lines for pulmonary edema before a CXR
  o No B-lines is an invitation for further volume loading
• Alveolar consolidation
  o Hepatization of the lung
• Pleural effusion
Thank You