Point of Care Ultrasound in the ICU
Do you hear what I hear
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Overview
- Basics of Ultrasound
- Different Ultrasound exams in the ICU and Ultrasound guided procedures
- Cases

A Case
- 61yo male with hz of DM and CAD with stenting 2 years ago, hz of melanoma
- 1 week of high fever and aches, 3 days of severe N/V unable to keep anything down, abd pain for last 24 hrs
- Has pretty much been in bed for the last 3 days
- Presents to the ER
  - Positive for flu and lactic acidosis, CE are normal
  - Volume depleted with only a mildly elevated Cr
  - KUB and CXR show no specific issues
  - Fires for Sepsis so got 2 L NS bolus with normalized BP in addition to antibiotics and Tamiflu
  - Admitted to the floor
A Case

- Couple of hours after admission, tele calls saying he is off the monitor
- Staff checks and he is found pulseless and apneic.
- Code blue called, with RSC after 2 rounds of epi and CPR. He is intubated during the code and moved to the ICU

A Case

- On arrival to the ICU-
  - Intubated
  - On Levophed, Epinephrine and Vasopressin for BP support
  - Unresponsive
  - Foley placed with only about 120cc of urine and no reported UOP since admission

Possible Causes

- Cardiac Arrest- MI
- Septic shock- flu/abdominal cause
- CHF from too much fluid too quick
- Hypovolemic shock
- PE/DVT
- Plus
  - No Urine output- cause of renal failure

Work up

- CE and Echo
- Abdominal CT, await cx
- Echo, CXR
- Not a specific
- CT angiogram/LE dopplers
- Renal Ultrasound

What about bedside Point of Care Ultrasound?
A little history

• Physicians have known for a long time that sound can give us insight into what is going on inside the body and aid in diagnosis

1816 by René Laennec

A little history

• By the mid 1850s, the stethoscope took on the similar shape it still has today
  – Really no change since the 1940s

• Many feel the Ultrasound Probe is the next step in this evolution

A little history

• Ultrasound was invented in 1942 and was first used for looking at brain lesions
  – 1950s by radiologists
  – 1960s by cardiologist
  – 1970s by OB/GYN
  – 1980s transitioned into other areas, battlefields, EMS and Military
  – 2000s used as a bedside tool in the ICU
Basics of Ultrasound

• Piezoelectric effect:
  – Crystals vibrate at given frequency when an alternating current is applied
  – Crystal acts as speaker and microphone
• The ultrasound probe contains these crystals that send out a high frequency sound wave, it then listens for their return
• The reflected signal gives information about the depth and nature of the tissues they encounter
• This is then translated into a gray scale image

Basics of Ultrasound

• Tissue Characteristics of Ultrasound
  – Air- near total reflector (scatter reflector)
    • Static appearing
  – Fluid- near total Propagation (no reflection)
    • Pure black
  – Bone- near total Reflection
    • Strong white with shadow behind it
  – Soft tissue- partial propagator, partial reflector
    • Reflects every time tissue impedance changes
      – Every interface

Anechoic (fluid)
Hypoechoic
Hyperechoic (bone, air, diaphragm, pericardium, gallstones)
Transducers

Frequency: 1 – 5 MHz
Maximum depth of penetration: 35 cm

Frequency: 6 – 13 MHz
Maximum depth of penetration: 6 cm

Why Ultrasound in the ICU
The Organizing Principals
• In critically ill patients, the physical exam has been shown to be limited and inaccurate
• Conceptually, physical examination and US have many similarities
• U/S is an imaging modality; the clinician uses the information to reach a diagnosis
• U/S is like CXR, CT, or PET; only useful if the clinician knows how to use the information
• Why Ultrasound vs other modalities
  – Portability - it comes to the patient
  – Lack of radiation
  – Repeatability
  – Absence of consumables
• Seeks to answer a limited number of questions
  – “Yes, no…..or….I do not know”
• Specificity over sensitivity
Crit Care Med 2006; 34:2153–2157

Thoracic Ultrasound
• Indications
  – Identify pleural fluid
  – Identify pneumothorax
  – Identify consolidation or pulmonary edema in lung
  – Identify abscess or mass
  – Access diaphragm function
• Limitations
  – Obesity
  – Heavy musculature
  – Edema
Thoracic Ultrasound

- **Lung Findings**
  - A lines = normal aerated lung
    - Horizontal lines parallel to the pleural line
    - A line predominance had a 90% specificity to rule out pulmonary edema
  - B lines = abnormality in the interstitial or alveolar compartment
    - 3 or more are abnormal
    - Pulmonary edema
    - ARDS
    - ILD
    - Pneumonia

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Ultrasound Thoracic Diagnosis

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPD/asthma</td>
<td>A lines + lung sliding</td>
<td>89%</td>
</tr>
<tr>
<td>Pulmonary Edema</td>
<td>Multiple B lines + lung sliding</td>
<td>97%</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>Normal profile + DVT</td>
<td>81%</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>Absent lung sliding</td>
<td>81%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>Ant alveolar cons, B lines - sliding</td>
<td>89%</td>
</tr>
</tbody>
</table>

Overall USG gave diagnosis in 90.5% patients

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DVT

- DVT in ICU ~10% (variable incidence)
- PE amongst the most common preventable causes of death in hospitalized patients
- Postmortem studies: PE in ~20-27% patients
- U/S is the now the gold standard for diagnosis
- Limited POC U/S exam is limited to
  - 4 sites of the femoral vein and the popliteal vein
  - >90% of DVTs occur at these sites
Echo

- This is a limited Echocardiogram
- Goals of limited Echo
  - Rapid evaluation of hemodynamics
  - Characterization of shock state
  - Guide management
  - Follow evolution and response to therapy

POC Limited Cardiac Echo

- Advantages
  - Immediately available
  - Can be repeated several times a day
  - Clinical context known to the person doing the Echo
- Challenges
  - Patient difficult to position
  - Difficult to image (on the ventilator, COPD etc)

Differences between Traditional Cardiac and Limited POC Echo

<table>
<thead>
<tr>
<th>POC Echo</th>
<th>Traditional Cardiac Echo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient needs volume?</td>
<td>Patient needs a valve?</td>
</tr>
<tr>
<td>Inotropes/pressors?</td>
<td>Aspirin/beta/ACE?</td>
</tr>
<tr>
<td>What is the SV and CO?</td>
<td>What is the EF?</td>
</tr>
<tr>
<td>Qualitative PAOP?</td>
<td>Segmental wall function?</td>
</tr>
<tr>
<td>Cardiac vs. respiratory?</td>
<td>Say what?</td>
</tr>
<tr>
<td>Passive leg raising?</td>
<td>Huh?</td>
</tr>
<tr>
<td>Dynamic indices?</td>
<td>What's that????</td>
</tr>
<tr>
<td>Code echo</td>
<td>Does not compute</td>
</tr>
<tr>
<td>Why is the patient dying?</td>
<td>Does patient need cath?</td>
</tr>
</tbody>
</table>
POC Limited Cardiac Echo

- Keep it simple
  - LV Function/Size
  - RV Function/Size
  - Atrial size
  - Pericardial effusion?
  - Signs for tamponade?
  - IVC size and variability
  - Valve morphology

The ejection fraction is 37.3%.56%

Feasibility and Utility of Goal Directed Echo

- Successfully performed diagnostic study 94%
- Correct interpretation 84%
- Change in management 37%
- New information but no change in management 47% of patients

POC Limited Cardiac Echo

• Pulmonary Embolism
  – See big Right Ventricle with a normal Lung exam
  – The identification of DVT on compression exam or thrombus in transit is diagnostic of venous thromboembolism.
  – Typical findings:
    • increased size of the pulmonary arteries,
    • RV dysfunction of varying degrees,
    • flattening of the interventricular septum, indicating both pressure and volume overloads,
    • TR, dilated RA, increased size of IVC
  – 77% sensitivity and 94% specificity

IVC

• Predictor of Volume responsiveness in shock
  – IVC diameter < 1cm in hypotensive patient indicates volume responsiveness
  – In a patient with sepsis who is passive on mechanical ventilation and in regular cardiac rhythm, IVC variability >12% indicates fluid responsiveness.
  – CVP=3 (0-5 mmHg)
    • IVC diameter <2.1cm, >50% collapsibility
    • Hypovolemic and distributive shock
  – CVP=15 (10-20mmHg)
    • IVC diameter >2.1cm, <50% collapsibility
    • Cardiogenic and obstructive shock

Code Blue Echo

• Can help identify
  – Signs of low cardiac function
  – Cardiac standstill
  – Severe hypovolemia
  – Cardiac Tamponade

• When to stop ACLS?
  – Cardiac standstill despite ACLS efforts
  – Thrombosed cardiac chambers
  – Thrombosed IVC with lack of flow
Abdominal Ultrasound

- CT will always prevail over US
- Quick screen to rule out intraabdominal catastrophe
- R/O free air/AAA/ischemic bowel/ascites peritonitis/ distended fluid filled bowel
- If sufficient ascites, consider immediate diagnostic pericentesis

Renal USG in critically ill

- Up to 10% of ICU patients receive some form of RRT
- Mainly to characterize type of renal disease- acute vs chronic
- In acute setting- detection of hydronephrosis
- Also effective in diagnosis bladder outlet or Foley obstruction

Procedures

- Vascular Access
  - Central lines
  - Peripheral access
- Paracentesis
- Lumbar Puncture
- Thoracentesis
- Pericardiocentesis
Back to our Case

• 61yo male with hz of DM, CAD and Melanoma
• 1 week of being in the bed with high fever and aches, severe N/V abd pain for last 24 hrs
• Admitted with Flu, and sepsis with initial stabilization with septic protocol
• Coded on the after being admitted to several hours earlier
• Now in the ICU, intubated, on three pressors and no UOP

Possible Causes

• Cardiac Arrest- MI
• Septic shock- flu/abdominal cause
• CHF from too much fluid too quick
• Hypovolemic shock
• PE/DVT

Work up

• CE and Echo
• Abdominal CT, small int
• EKG, CRP
• ABG, INR
• CT angiogram if doubt

4 hrs to do
Pt has to Move

10 minutes and done at bedside

Our Case

Thoracic Ultrasound

• A lines seen throughout
• Small amount of consolidation vs atelectasis at the bases
• Trace Pleural effusion
• No real cause there

Abdominal Ultrasound

• No free fluid or air
• Kidneys present and no obvious hydronephrosis
• Bladder collapsed around Foley
• Renal issues are probably metabolic
• No perforated viscous
Our Case

Limited Echo
- Hyperdynamic heart
- Good volume status
  - IVC is plump
- No signs of tamponade
- Large right ventricle
- And ??

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Our Case

DVT study

Our diagnosis
- PE with Left Femoral DVT
- Next Step: Probably TPA
- 10 minutes to diagnosis with little to no risk to the patient
One more Case  
(Your Results May Vary)

- 54 yo female with remote hz of GBS
- Admitted with small bowel obstruction and underwent ex lap with lysis of adhesions
- Normal post op course for 1st 24 hr
- This AM developed worsening respiratory distress
- Moved emergently to the ICU

One more Case  
(Your Results May Vary)

- On arrival to the ICU, patient was in marked distress and unable to lie flat.
- ABG showed rising pCO2
- BP started to drop
- Emergently intubated but BP continued to worsened
One more Case
(Your Results May Vary)

- I had my portable ultrasound

One more Case
(Your Results May Vary)

- I had my portable ultrasound

One more Case
(Your Results May Vary)

- I had my portable ultrasound
One more Case
(Your Results May Vary)

• \(?\) Cardiac tamponade but from a pleural effusion
• Emergent Thoracentesis was done at the bedside
  – 1200cc of pink colored clear fluid
  – Concern for IV fluid
• After thoracentesis patient immediately improved
  – Hrt Rate: 165 → 113
  – RR: 20 → 20
  – BP: 118/87 → 129/88
  – POX on 100% → 100%

One more Case
(Your Results May Vary)

• Diagnosis:
  – Cardiac Tamponade from rapidly accumulating Pleural effusion due to misplaced Central line
• Old Central line pulled and new one placed
• Patient was extubated the next day
• Discharged home and was seen with followup with no pulmonary sequella
• From time of admission to ICU to stabilization after thoracentesis less then 90min
  • Would not have been possible without rapidly available bedside POC Ultrasound

In the End, What really is POC or Critical Care Ultrasound

• A Rapid, patient-focused bedside US scan
  – Initial Rapid scan: lungs, IVC< heart
  – Then after initial resuscitation other specific areas as indicated:
    • Heart/ Lungs/ Abdomen/ Leg Veins
• Bloody Sick = Bloody Obvious
  – Not looking for a small pneumothorax or mild CHF
  – If patient is unstable, the U/S signs should be obvious