ROLE OF ULTRASOUND IN THE ICU

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Ultrasound

- **SONUS**
  - Latin word
  - Means sound

- **Graphien**
  - Greek word
  - Means to write

- Based on the principle of sound waves
In 1942 the first use of ultrasound as a medical device was developed by Karl & Friederich Dussik for imaging brain tumors and the cerebral ventricles.

Early Ultrasound

- 1950’s by radiologists
- 1960’s by cardiologists
- 1970’s by OB/GYN
- 1980’s ultrasound use transitioned to other fields and for use in battlefields, EMS and military
Ultrasound Advantages

- Portable
- Light weight, hand held models
- No detrimental effects with scanning
- Minimal space needed
- No patient transport
- Immediate results
- Allows for direct acquisition of data
Ultrasound in the ICU

- Procedures
- Use in respiratory failure
- Use in shock
- Routine evaluation of ICU patient

Procedures

- Vascular Access
  - Central lines
  - Peripheral access
- Paracentesis
- Lumbar Puncture
- Thoracentesis
- Pericardiocentesis
Vascular Access

- 5 million central lines per year in U.S.
- Complication rate of 15%
- Arterial puncture and pneumothorax rate of close to 21%
- Up to 35% attempts are not successful

Feller-Kopman Chest 2007;132:302-309

Ultrasound Use in Vascular Access

- Systemic review and meta analysis of RCT
- 18 Trials (1646 participants)
- Ultrasound resulted in a significantly lower failure rate cannulating the internal jugular- relative risk of 0.14
- Lower failure rate on the first attempt
- Fewer complications with placement

Hind, D et al BMJ 2003; 327
Ultrasound Use for Vascular Access

- Meta-Analysis comparing ultrasound guidance to landmark techniques
  - Decreases need for multiple attempts by 40%
  - Decreases complications by 78%
  - Decreases placement failure by 64%

  Randolph et al Crit Care Med 1996 Dec 24(12) 2053-2058

- Agency for Healthcare Research and Quality listed real time ultrasound guidance as 1 of the 12 most highly rated patient safety practices designed to decrease medical errors

Ultrasound Use for Vascular Access

- Ultrasound improved vascular access even in seasoned providers
- Decrease in infectious complications
- May be related to decrease number of attempts
- More attempts may also lead to break down in aseptic technique

Kirakitsos et al Critical Care 2006; 10(6); 1-8
Vascular Access

- Differentiate artery and vein
- Methods
  - Compression
  - Color Flow Doppler
  - Distal Augmentation
  - Spectral Doppler

Vein vs. Artery

- Vein
  - Compressible
  - Thin walled
  - Ovoid in shape
  - Can change in size with respiration
- Artery
  - Difficult to compress
  - Thick walled
  - Circular in shape
Ultrasound of Peripheral Vessels

Doppler Effect

- Apparent change in the frequency of a wave caused by the relative motion of the source of the wave and the observer
- BART
  - Blue away
  - Red towards
Doppler of Peripheral Vessels

Doppler of Peripheral Vessels with Probe towards the Head
Differentiation of Vessels

- Artery has pulsatile flow
- Distal Augmentation - Vein will fill with blood when area distal to the vessel is compressed

Transverse Approach

- Locate target vessel
- Anesthetized skin
- Puncture skin adjacent to probe
- Locate needle tip - there will be acoustic shadowing and reverberation artifact
- “Step wise approach” - move probe as needle is inserted
- Advantage that you are able to keep artery and vein in screen
Longitudinal Approach

- Marker dot is towards the needle
- Move the needle tip not the probe
- Technically more difficult but provides more information regarding location of the needle to the target vessel
- Always start with the transverse approach to identify the vein and artery
Peripheral Venous Access

- 3-1-3 Rule
- Veins should be 3cm straight
- Veins should be <1 cm deep
- Veins should be at least 3 mm in diameter
Lung Ultrasound Uses

- Identify pleural fluid
- Identify pneumothorax
- Identify consolidation or pulmonary edema in lung
- Identify abscess or mass
- Access diaphragm function

Limitations

- Obesity
- Heavy musculature
- Edema
- Inability to properly position patients
- Full image documentation is impractical
Technique

- Phase array transducer for deep structures in the thorax
- Linear vascular transducer for chest wall and pleura

Ultrasonograph scan lines.

TECHNICAL CONSIDERATIONS

Technique for Pulmonary Scanning

Move systematically to examine each rib space

3rd Rock Ultrasound

2009

Utilize the liver as the acoustic window for the right hemithorax

Utilize the spleen as the acoustic window for the left hemithorax

3rd Rock Ultrasound

2009
Lung Sliding

- Shimering echogenic linear structure examined for movement
- Movement of visceral pleura against the parietal pleura
- Indicates no pneumothorax at this interspace
- No lung sliding = pneumothorax
- Leading edge

Sliding Lung
Normal Lung

Normal pleural line.

M-Mode for PTX

- Seashore sign for normal lung
- Barcode sign for PTX

Seashore sign
Barcode sign

Normal Lung Findings

- A lines = normal aerated lung
  - *Horizontal lines parallel to the pleural line*

- B lines = abnormality in the interstitial or alveolar compartment - 3 or more is abnormal
  - *Pulmonary edema*
  - *ARDS*
  - *ILD*
  - *Pneumonia*
Normal aeration pattern with A-lines.


B-lines.


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A-Lines and B-Lines

- Prospective study of 102 patients who underwent lung ultrasound and pulmonary artery catheterization
- A line predominance had a 90% specificity, 67% sensitivity, 91% positive predictive value, 65% negative predictive value for a wedge ≤13

Lichtenstien DA et al CHEST 2009; 136:1014-1020

Pneumonia

- Consolidated lung has similar echogenicity to liver and spleen
- Look for airbronchograms
Lung Mass

- Ultrasound is more accurate than chest CT scan for detection of chest wall invasion
- 90 patients studied- underwent U/S, CT scanning and surgical staging
- Ultrasound sensitivity 89%, specificity 95%
- CT sensitivity 42%, specificity of 100%
- U/S can be limited by adhesions, tumors behind bone

Bandi, V et al Chest 2008; 133;881-886
Assessment of Diaphragm Function

- Can angle the beam thru the liver or spleen to image diaphragm thru its entirety
- Absent or paradoxical movement indicates paresis

Frozen image of diaphragm with arrows indicating caudad and cephalad direction.

Thoracentesis

- Scan in mid-scapular plane
- Sagittal orientation
- Identify ribs
- Identify diaphragm, liver or spleen
- Make sure rib space above and below puncture site has fluid present throughout respiratory cycle
- Check for sliding lung pre and post procedure

Empeyema
Pitfalls

- Image quality affected by
  - Obesity
  - Soft tissue edema

- Echogenic Effusions
  - Complicated pleural effusion
  - Empyema
  - Hemothorax
  - Fibropurlant collections

Point of Care Echocardiography

- FOCUS: Focused Cardiac Ultrasound, eFAST, Goal directed echo
- 5 views
  - Parasternal long
  - Parasternal short
  - Apical 4 chamber
  - Subcostal
  - IVC view
Goals of Limited Echo

- Rapid evaluation of hemodynamics
- Characterization of shock state
- Guide management
- Follow evolution and response to therapy

Complete Echo

- Time delay in performing
- Time delay in interpretation
- Not repeated in time
- Clinical disassociation
- Goal directed echo is a supplement not a replacement
Can Intensivists Perform Echocardiograms?

- Royse CF, Seah JL, Donelan L, Royse AG: Point of care ultrasound for basic haemodynamic assessment: novice compared with an expert operator.
Feasibility and Utility of Goal Directed Echo

- Prospective, observational study
- Intensivists trained with 10 one hour tutorials
- Performed a limited goal directed echo, interpreted images and determined if echo added any information
- Cardiologist repeated exam and gave an opinion of technical adequacy and accuracy of interpretation


Feasibility and Utility of Goal Directed Echo

- Successfully performed diagnostic study 94%
- Correct interpretation 84%
- Acquisition time 10.5 minutes + 4.2 minutes
- Change in management 37%
- New information but no change in management 47% of patients

Goal Directed Echo - 5 Questions

■ Is there an imminently life-threatening cause for shock?
■ Is the shock state likely to be fluid responsive?
■ Is there evidence of pump failure? If so, what is the pattern and what is the appropriate therapeutic response?

Schmidt, G.A. et al CHEST 142, 4, October 2012, 1042-1048

GDE- 5 Questions

■ Is there more than one cause for the shock state or are there findings that will complicate management of hemodynamic failure?
■ Is the cause of the shock state other than cardiac origin? Would ultrasonography of another organ system be useful in rendering a diagnosis?

Schmidt, G.A. et al CHEST 142, 4, October 2012, 1042-1048
Etiology of Shock

- Physician performed goal directed ultrasound protocol for diagnosis and management of hypotension
  - Early goal directed ultrasound led to a more focused differential diagnosis
  - Median number of diagnoses of 4 vs. 9
  - More accurate physician impression of final diagnosis

Jones et al Crit Care Med 2004 Vol 32 No 8 1703-1708

Volume Status

- IVC diameter < 1cm in hypotensive patient indicates preload responsiveness

- Intubated patients who are passively breathing measurement of IVC, respiratory variation in IVC size and small hyperdynamic LV indicate preload sensitivity Kaplan A et al CHEST 2009; 135: 529-535

- In a patient with sepsis who is passive on mechanical ventilation and in regular cardiac rhythm, IVC variability >12% indicates fluid responsiveness. IVC variability is calculated as follows:

  \[
  \text{maximum IVC diameter} - \text{minimum IVC diameter} \div \text{mean IVC diameter}
  \]

Barber et al Intensive Care Med 2004; 30:1740-1746
IVC

- 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

  - American Society of Echocardiography 2010

Volume Status

- 65 year old male admitted to the ICU with presumed tumor lysis syndrome. Received 10 liters over night and currently on 3 pressors
IVC Collapse

What do you mean my echo was a technically difficult study?
Cautionary Note

- Study in France with ER physicians using prehospital ultrasound found poor correlation between physicians and experts in echocardiography in LV function, RV size, pericardial effusion, IVC evaluation. (Charron et al. European Journal of Emergency Medicine, 2015, 22:17-22)
- Limited training
- Pocket ultrasound used
- Prehospital setting

Summary

- Ultrasound critical for procedures including central lines, thoracentesis and paracentesis
- Pulmonary ultrasound helpful for evaluation of the lungs, pleural effusions, pneumonia, respiratory failure and diaphragm function
- Goal directed echo useful in determining etiology and management of shock