Overview of Ultrasound in Critical Care

Dr. Gyanendra Agrawal

Senior Resident

Deptt. of Pulmonary Medicine

Need for USG

- In critically ill patients physical examination is quite limited and inaccurate
- USG has potential to reinvigorate physical exam^{n}, improving accuracy
- Imp attributes: portability, lack of radiation, repeatability, absence of consumables, being battery powered
- Information can be stored for documentation, transmission, consultation

Can J Surg 2000;43:207–211
Am J Med Sci 1990; 299:175–178
Crit Care Med 2006; 34:2153–2157

Whether we should be doing it ???

- Basic ultrasound skills should be part of the armamentarium of critical care
- Far from being competitive or conflicting, it is complementary
- Brief (10 hrs) formal training in handheld ECHO system, intensivists able to perform limited TTE in 94% and interpreted correctly in 84%- changed management in 37% of patients
- ACEP/ SCCM guidelines include USG by intensivists

Intensive Care Med (2008) 34:243–249
J Cardiothorac Vasc Anesth 1998; 12:10–15
ACEP Emergency Ultrasound Guidelines, 2001

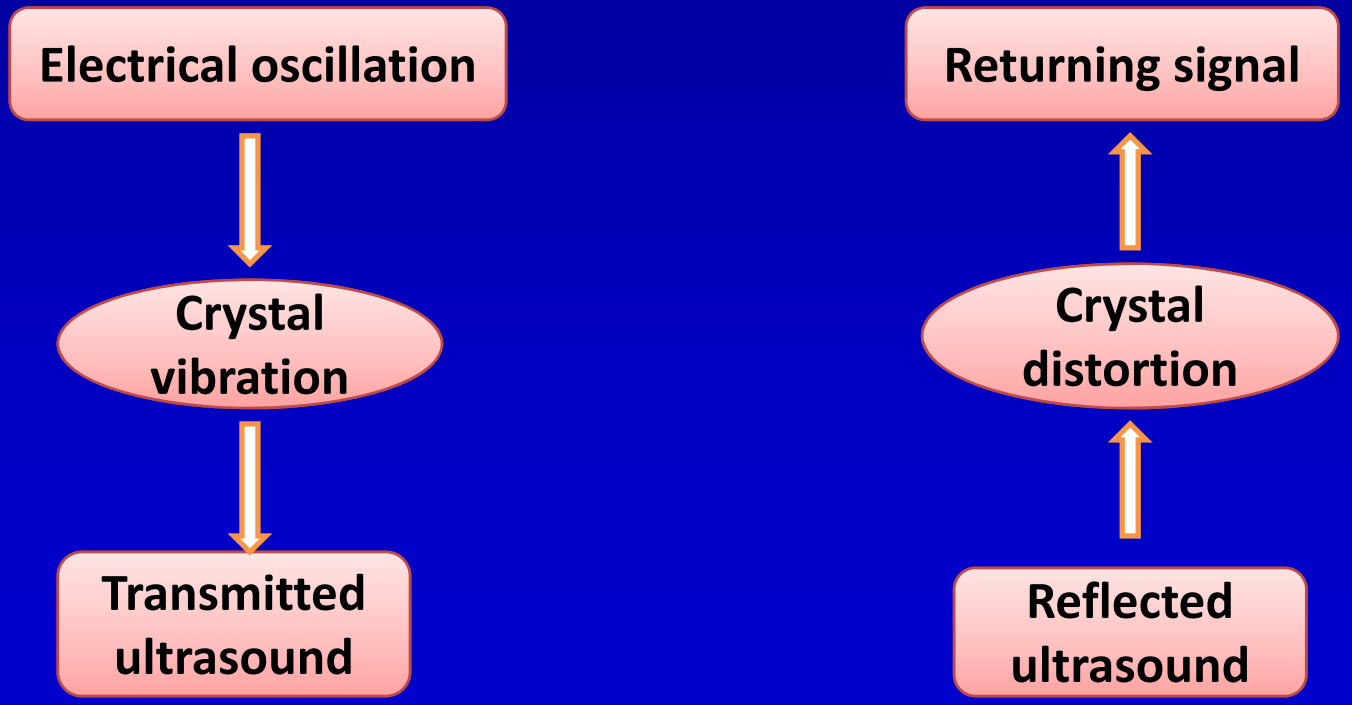
What is Ultrasound?

- Human sensitivity: 20 - 20,000 Hz
- Ultrasound: >20,000 Hz
- Diagnostic Ultrasound: 2.5 - 14 MHz
- Frequency is determined by the sound source only and not by the medium in which the sound is traveling

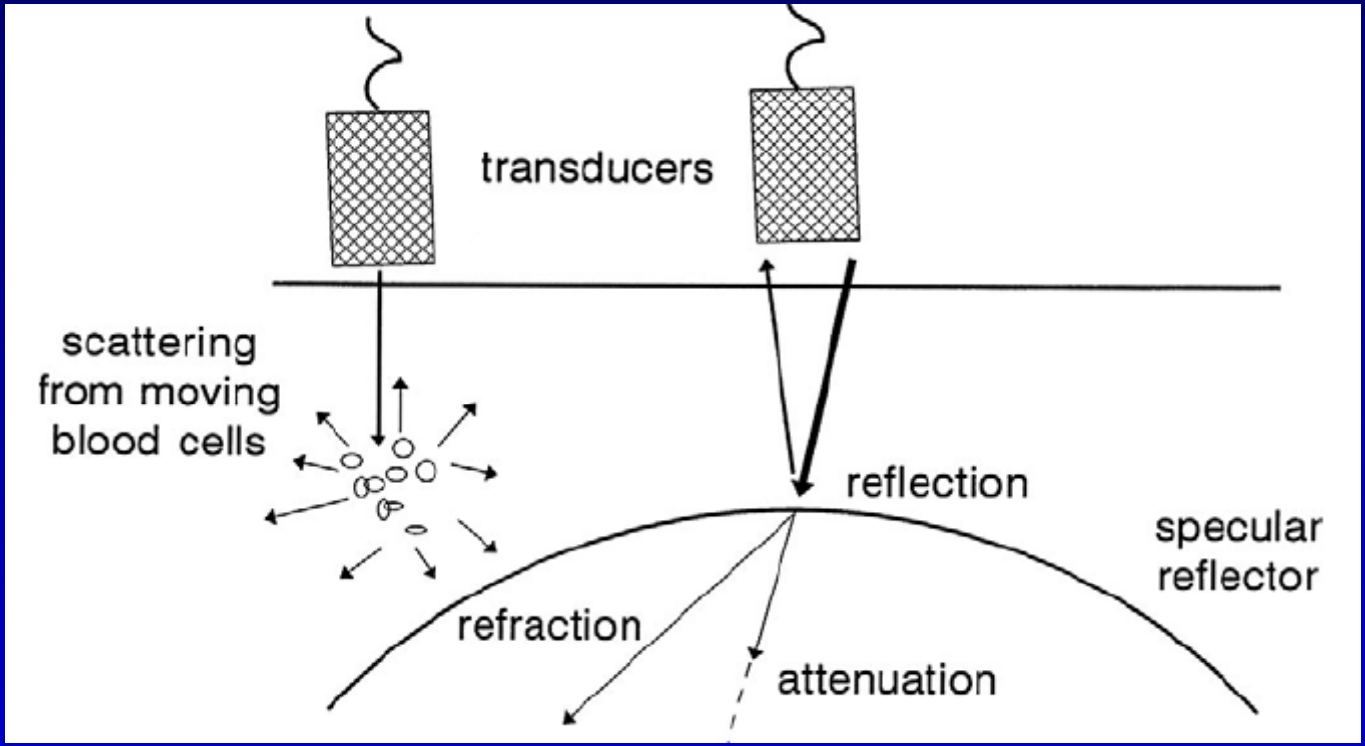
Ultrasound Production

Piezoelectric effect:

- Crystals vibrate at given frequency when an alternating current is applied
- Crystal acts as speaker and microphone



Basic physics



Most of the reflection occurs at interfaces between tissues having different echo density

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USG image

- Reflected signal gives information about depth and nature of tissue

- On the grey scale,
  high reflectivity (e.g. bone) is white
  low reflectivity (e.g. muscle) is grey
  no reflectivity (e.g. air) is black

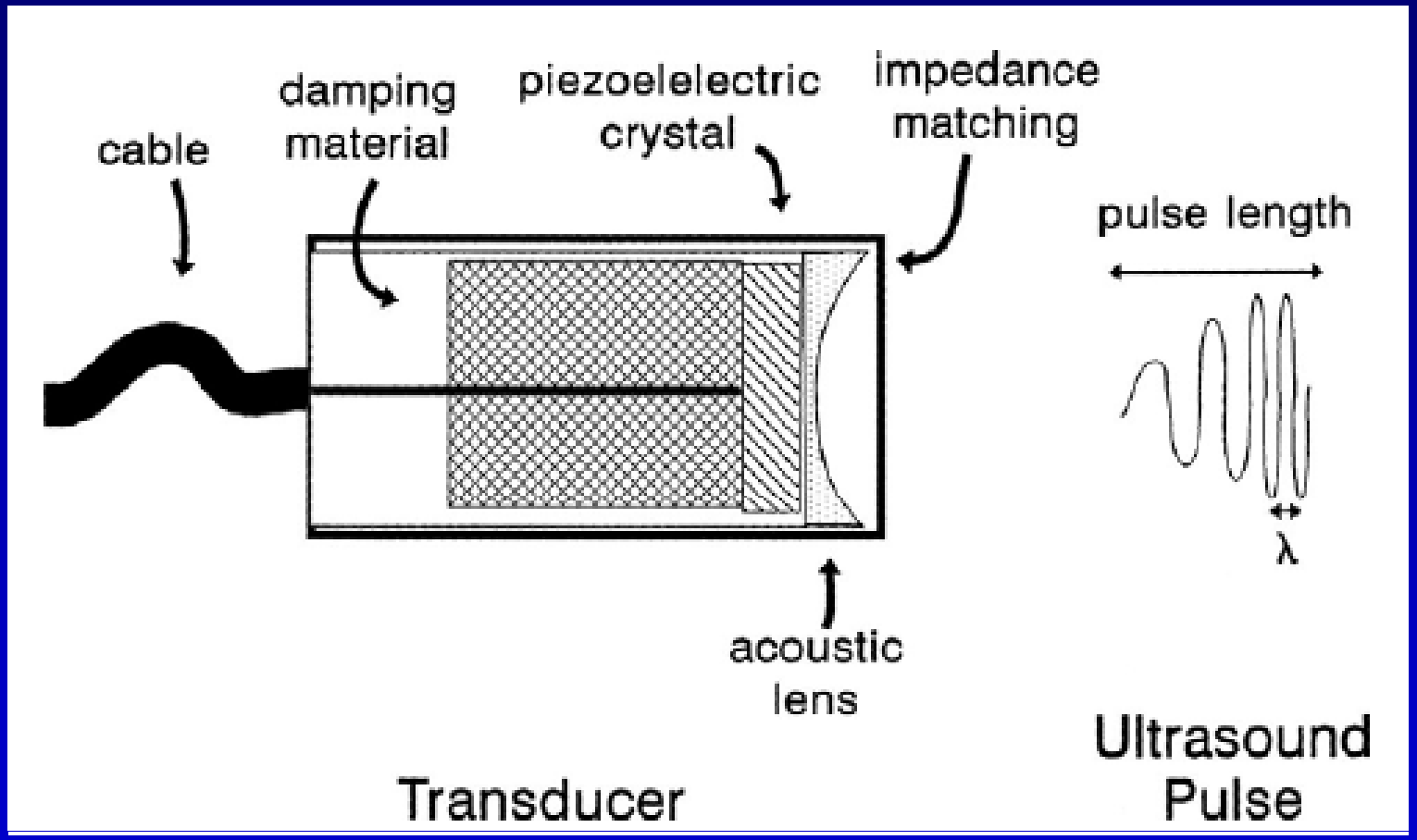
- Deeper structures on lower portions of display screen and superficial on upper portion

Basic physics

- Velocity= frequency x wavelength

Frequency	Penetration	Resolution	Study depth
2.5- 3.5	good	less	deep
5.0-7.5	less	good	superficial

Transducer



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Transducers

- Formats
  - – linear- rectangular field of view
  - – sector- pie-shaped field of view
- Linear array transducers
  - - piezoelectric elements linearly arranged
- Phased array transducers
  - - smaller scanning surface
  - - good for echocardiography
  - - more expensive
  - - elements are activated with phase differences to allow steering of the ultrasound signal

Scanning Skills

- Try different windows
- A lot of gel

Transducer movements:

- Rotate
- Angle (Tip-toe)
- Pivot (fan-shaped movement)

Transducer placement basics:

- longitudinal view
- transverse view
- coronal view

Principle of Doppler

- Pitch of the horn sound is higher when it approaches you than when it goes away
- Change of frequency (Doppler shift) depends on speed of automobile and the original frequency of horn sound
- Doppler utilizes ultrasound reflected by moving RBC's
- Tells about flow velocity and flow direction as well
- **B**lue **A**way **R**ed **T**owards (BART)

Continuous wave Doppler

- Transmits and receives ultrasound continuously
- Used for rapid scanning in search of high velocity signals and abnormal flow patterns
- Cannot precisely localize the returning signal
- By using CW Doppler signal of tricuspid valve, pulmonary artery pressures can be calculated

Pulsed wave Doppler

- Transmits ultrasound in pulses and waits to receive it after each pulse
- Because of time delay it cannot detect high velocities
- Used to localize velocity signals and abnormal flow patterns picked by CW Doppler

USG in venous thrombosis

- 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

- USG helpful in:
  - diagnosing DVT
  - to know the extent of DVT
  - to differentiate acute and chronic DVT

Crit Care Med 2007 Vol. 35, No. 5 (Suppl.)

USG in venous thrombosis

	Normal	Nonocclusive thrombus	Occlusive thrombus
Direct compression	Complete obliteration	Partially compressible	Not
Color flow (Color Doppler)	Completely filled	Color filling in and around thrombus	Absent
Signal phasicity (PW Doppler)	(n) phasic flow	Continous flow	Absent
Augmentation	Present	Some response	--

USG in thoracic diseases

- USG quite useful in thoracic diseases, previous incorrect dogma

- Acute respiratory disorders amenable to diagnosis with ultrasound are:
    - pleural effusion
    - alveolar consolidation
    - interstitial syndrome
    - pneumothorax

Seven principles of lung USG

- A simple, unsophisticated USG machine is perfectly adequate
- Artifacts due to air water mixing. Two types of diseases-
  - ‘dependent’ e.g. effusion
  - ‘non dependent’ e.g. pneumothorax
- All lung patterns arise from the pleural line
- Largely based on the analysis of artifacts
- Lung patterns are largely dynamic
- Majority of acute lung disorders abut the lung surface
- Precise areas to define with physical examination

Ultrasound areas of chest

Microconvex probe is used- allows satisfactory analysis of the intercostal space and veins

Chest 2008; 134:117–125

Interstitial syndrome: B + lines

- Comet-tail artifact
- Arising from the pleural line
- Hyperechoic
- Well defined
- Spreading up indefinitely
- Erasing A lines
- Moving with lung sliding

Chest 2008; 134:117–125

Ultrasound profiles

Profiles	Description	Suggestive of	Rules out
A profile	predominant A lines plus lung sliding at the anterior surface	COPD, PE, posterior pneumonia	Pulm edema
B profile	predominant B lines	Pulm edema	COPD, PE, pneumothorax
A/B profile	anterior-predom B lines at one side, predom A lines at other	pneumonia	
C profile	anterior alveolar consolidation		

Ultrasound diagnosis

		Sensitivity	Specificity
COPD/ asthma	A lines + lung sliding	89%	97%
Pulmonary edema	Multiple B lines + lung sliding	97%	95%
Pulm embolism	Normal profile+ DVT	81%	99%
Pnemothorax	Absent lung sliding	81%	100%
Pneumonia	Ant alveolar cons, B lines - sliding	89%	94%

Overall USG gave diagnosis in 90.5% patients

Chest 2008; 134:117–125

Pleural effusion

- With CT as a gold standard, sensitivity and specificity of ultrasound are >90%
- No technique for measuring the exact volume
- If >10 mm – diagnostic tap indicated

- Liquid with mobile particles (plankton sign) or septa is suggestive of exudate, hemothorax, or purulent pleurisy

- Check for an inspiratory enlargement of the interpleural space of >15 mm, with effusion visible at the adjacent upper and lower intercostal spaces

Anesthesiology 2004; 100:9–15

Alveolar Consolidation

- Contains mainly fluid and little air
- 98.5% abut the pleura
- Using CT as gold std- 90% sensitivity and 98% specificity
- Abscesses or necrotizing areas within the consolidation can be detected
- Better than conventional radiographs

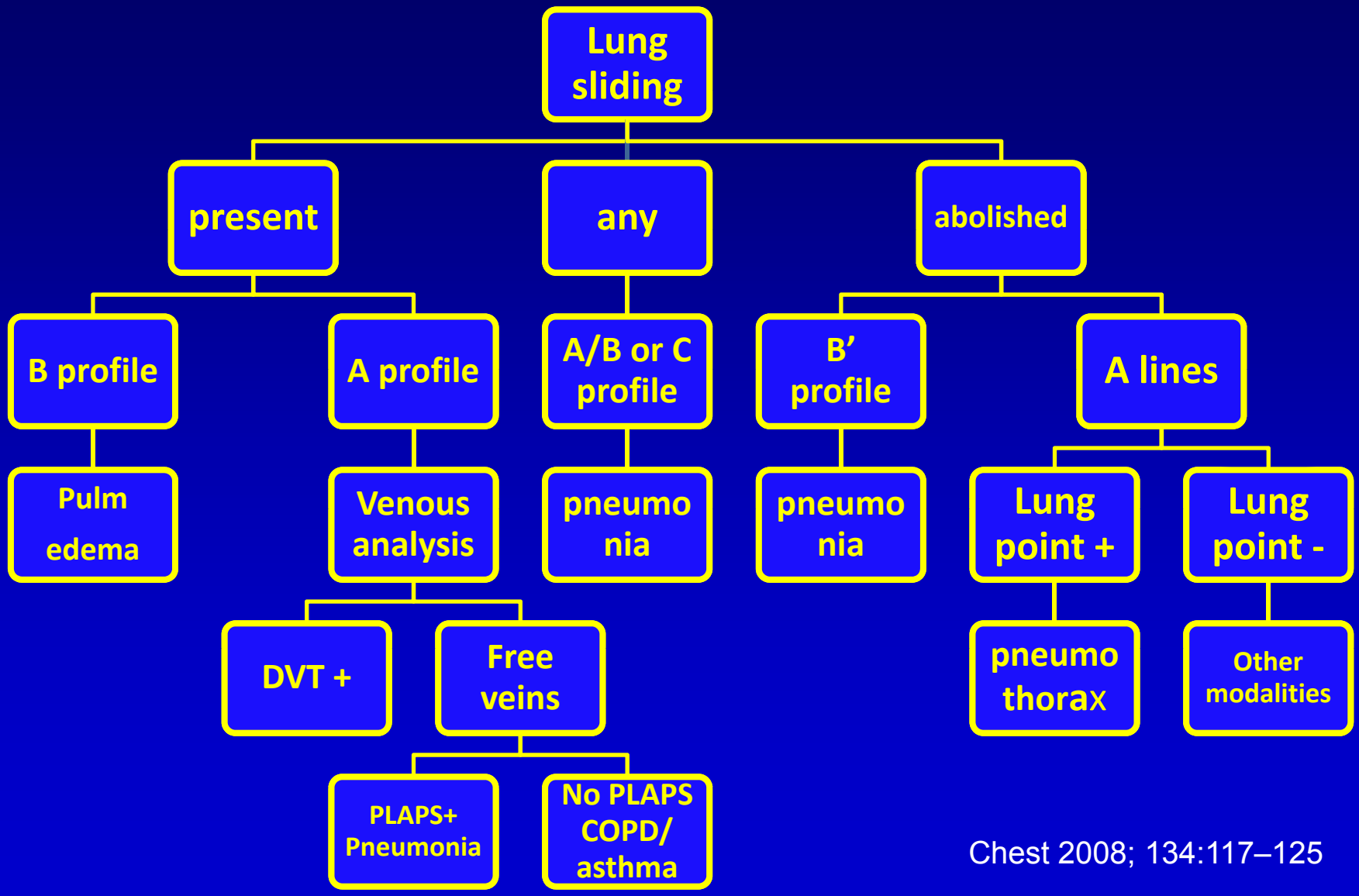
Intensive Care Med2004; 30:276–281

Pneumothorax

- Can ultrasound detect air ? ----------YES !!!!
- Basically artifacts providing clinical information
- Absent lung sliding (NPV 100%)
- Mainly helps in ruling out pneumothorax
- Volume can be assessed
- Saves time

Chest 1995; 108: 1345–1348

The BLUE Protocol



Chest 2008; 134:117–125

USG in acute respiratory failure

- Bedside Lung Ultrasound in Emergency—the BLUE protocol
- Saves ti
- Decreas
- Lung USG nearly equivalent to CT in diagnosing most diseases

When your patient is blue
Perform BLUE protocol

Anesthesiology 2004; 100:9–15

- Can be repeated any time

Bedside echocardiography

- Hemodynamic instability
- Infective endocarditis
- Aortic dissection and rupture
- Unexplained hypoxemia
- Source of embolus
- Complications after cardiothoracic surgery

TTE vs TEE

- Poor acoustic window in ICU patients:
  - MV interposing inflated lung bet^{n} heart & chest wall
  - surgical emphysema, obesity, COPD
  - surgical wounds, dressings, tapes, tubings
  - lack of patient cooperation
  - difficulty in moving patients
- Failure rates of TTE 30-40%, TEE 10-15%

Chest 1993; 104:861–866
J Trauma 2002; 52:280–284

Transesophageal echo

- High image quality vital
  - Aortic dissection
  - Intracardiac thrombus
  - Assessment of endocarditis
- Inadequately seen by TTE
  - Thoracicaorta, Left atrial appendage, Prosthetic valves
- Inadequate image clarity with TTE
  - Severe obesity, Emphysema
  - Mechanical ventilation with high-level PEEP
  - Presence of surgical drains, surgical incisions, dressings
- Acute perioperative hemodynamic derangement

Echo windows

- Left parasternal
- Apical
- Sub-costal
- Right parasternal
- Suprasternal

Echo in hypotension

1. All critically ill, HD unstable patients

2. Suspected aortic dissection

3. Critically injured trauma patients when:
   - serious blunt or penetrating chest trauma
   - MV multiple trauma pt
   - suspected pre-existing valvular or myocardial disease
   - mediastinal widening
   - potential catheter, guidewire or pacer electrode injury

Echo leads to change in therapy in about 25%

Anaesth Intensive Care 1998; 26:22-25

Echo in hypotension

- Cardiogenic shock- by assessing contractility
- Hypovolemic shock- by assessing preload
- Pericardial tamponade
- Pulmonary embolism
- Aortic dissection
- LVOT obstruction

TTE successful in 50% of attempts, TEE in 90%

Mayo Clin Proc 1995; 70:1012–1014
Am Heart J 1990; 119:1083–108

Echo in hypotension

- Preload: LVED volume, LVED area (LVEDA), superior vena cava collapsibility, inferior vena cava size, and fluid responsiveness

- Criteria for diagnosing hypovolemia:
  - end-diastolic diameter of <25 mm,
  - systolic obliteration of the LV cavity, and
  - LV end-diastolic area of <55 cm^2

- "Kissing papillary muscle sign"- end systolic cavity obliteration- 100% sensitivity and 30% specificity

Anesthesiology 1995; 83:285–292

Echo in hypotension

- Contractility:
  - New or worsening wall motion abnormalities may indicate acute ischemia
  - Global LV systolic dysfunction e.g. sepsis, myocarditis

- Ejection fraction = SV/ EDV
  (Modified Simpson's method calculates ejection fraction in two planes and averages them)

- RV function: mid-esophageal four-chamber view is the most useful for RV volume, size, function of the base, free wall, and the apex

IVC variability

- Dilated IVC (>20 mm) without a normal inspiratory decrease in caliber (>50% with gentle sniffing) usually indicates elevated RA pressure
- Less specific in MV pts. as IVC dilated
- So a small IVC reliably excludes elevated RA pressure

Intensive Care Med (2008) 34:243–249

IVC variability

- Feissel et al- 39 patients on MV with septic shock
- Volume load (8 mL/kg 6% hydroxyethylstarch over 20 mins)
- Variation in IVC diameter greater in responders of volume loading
- 12% cutoff in variation: PPV 93% and NPV 92%

Intensive Care Med 2004; 30:1834–1837

Pericardial tamponade

- Chambers collapse when pericardial pressure exceeds chamber pressure
- Occurs in diastole before systole and on the right side before left side
- Most sensitive 2D echo finding is RV collapse during diastole
- If RA collapse lasts longer than a third of the R-R interval- specific sign

Pericardial tamponade

- Blunt or penetrating chest trauma
- Complication of MI (ie, ventricular rupture)
- Uremic or infectious pericarditis
- Metastatic disease or other systemic processes
- Proximal ascending aortic dissection
- Compressive hematoma after cardiac surgery
- Iatrogenic (e.g. central line placement, percutaneous coronary interventions)

Pulmonary embolism

- Consider in a pt with increased alveolar arterial O_2 gradient, HD instability, and no other obvious expln^n
- TEE: 70% sensitivity and 81% specificity
- 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
- McConnell sign: 77% sensitivity and 94% specificity

Ann Emerg Med 2000; 35:168–180
Heart 2001; 85:628–634
Am J Cardiol 1996; 78:469–473

Infective endocarditis

- High index of suspicion as classical findings absent
- Multiple indwelling catheters, TPN, severe underlying disease, altered GI mucosal permeability, and prolonged MV increase likelihood of bacteremia
- High risk echo features:
  - large or mobile vegetations,
  - valvular insufficiency,
  - suggestion of perivalvular extension,
  - intracardiac abscesses,
  - new dehiscence of prosthetic valve

Infective endocarditis

- Sensitivity of 58-62%, and specificity of 88-98%

- TEE should be reserved for:
  - clinical likelihood high and TTE negative
  - prosthetic valve endocarditis
  - complications of endocarditis
  - unknown source of *S aureus* bacteremia
  - positive blood c/s despite antibiotics

Chest 2005; 128:1766–1781

Renal USG in critically ill

- Upto 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
- Indicated as a possible monitor of splanchnic perfusion

Semin Ultrasound CT MR 1997; 18:22–26

Transcranial Doppler in Neurocritical care

- Detection of vasospasm in patients with SAH
- Noninvasive estimation of ICP and cerebral perfusion pressure(CPP) in severe traumatic brain injury
- Assessment of cerebral pressure auto-regulation and CO2 reactivity – prognostic implications
- Setting of clinical brain death

Subarachnoid Hemorrhage: Detection of Vasospasm

- Principle- velocity of blood flow inversely related to area of vessel
- Severe vasospasm- significantly higher mortality
- 15% to 20% risk of stroke or death
- Cerebral angiography of brain – gold standard
- Transcranial Doppler determines the flow velocities in the basal cerebral arteries
- Probe placed in temporal area determines velocities in middle cerebral artery (MCA)
- Flow velocities in the proximal ACA, terminal ICA, and PCA can also be recorded

Crit Care Med 2007 Vol. 35, No. 5 (Suppl.)

Detection of Vasospasm

- Different intracranial vessels have different velocities criteria for diagnosing vasospasm
  - Sensitivity -38% to 91%
  - Specificity -94% to 100%,

<u>Limiting factors:</u>

- Improper vessel identification
- Increased collateral flow
- Hyperemia/ hyperperfusion
- Cervical ICA stenosis or occlusion
- Operator inexperience
- Aberrant vessel course
- Insensitive for detecting distal vasospasm

J Neuroimaging 1996; 6:8–15

Detection of Vasospasm

- As ICP increases and CPP decreases, flow velocity decreases
- Using the pulsatility index, Bellner et al demonstrated that ICP of 20 mm Hg can be determined with a sensitivity of 0.89 and specificity of 0.92
- May ultimately allow intensivists to optimize CPP and ventilatory therapy for the individual patient
- Clinical utility yet to be tested in clinical trials

Surg Neurol 2004; 62:45–51

Brain Death

- Brief systolic forward flow or systolic spikes and absent/reversed diastolic flow
- No demonstrable flow in a patient in whom flow had been clearly documented on a prev TCD
- Sensitivity-88%
- Specificity-98%

Acta Neurol Scand 2006; 113:426–432

USG guided interventions

- Central line placement
- Thoracentesis, paracentesis
- Drainage of wide variety of abscesses
- Image guided biopsies and FNAC
- Percutaneous nephrostomy
- Percutaneous cholecystostomy
- IVC filter placement
- Arterial catheterization

USG guided interventions

- Portable
- Allows imaging in numerous planes
- Allows real time visualization of needle and catheter
- Color Doppler flow to accurately identify vessels
- Reduced exposure to radiation and nephrotoxic contrast agent

Central line placement

- Real time USG to assess anatomy and patency
- Monitor passage of needle through the procedure
- To find alternate routes of access

- Ultrasound significantly
  - decreases need for multiple attempts
  - decreases failure rates for cannulation
  - decreases complications
  - more rapid access

Clin Radiol 2006; 61:13–22

USG guided interventions

- Method of catheter placement:
  - Trocar technique
  - Seldinger technique

- Size of catheters:

6-8 Fr	Percutaneous cholecystostomy
8-14 Fr	to drain empyema
12-16 Fr	abdominal abscesses
19 Fr	complex infected fluid collections

Thoracentesis

- Anechoic fluid- transudative
- Septations, debris, echogenic material, thickened pleura- almost always complex effusion
- USG helps in differentiating atelectasis, consolidation, mass, elevated diaphragm
- Specially indicated in MV, obese, loculated or small fluid collections
- USG helpful in catheter manipulation or redirecting it and changing or upsizing drain

USG guided percutaneous drainage

- Facilitate cure thus avoiding risks of surgery and GA
- Temporary procedure that buys time
- Multistage → single stage procedure
- Operation may be impractical or impossible in light of marginal clinical status of critically ill pts

Finally….

- USG marries the human hand to the digital age, allowing the examiner to interrogate anatomy and physiology with instantaneous visual gratuity
- USG may appear complex at first sight but simply requires a change in thinking
- Once the process has been learned, a step-by-step use will make it a routine