Image optimization for critical care US
Although we assume you are already familiar with focused US in the ED, it might not hurt to revise the basics:

- **Machines & transducers**
- **US appearance of normal tissues**
- **Artefacts**
- **General tips to improve your image**
- **What the hell is...?**
  - Auto optimize
  - Tissue harmonic imaging
  - Read & write zoom
  - Dynamic range
  - Line density
- **Probe & presets for critical care US**
- **M-mode**
- **Doppler**

**Machines**

A variety of ultrasound machines exist. For the purposes of an Emergency/Resuscitation room scan, the priority is a limited, goal directed scan used to answer a specific clinical question.

Whichever machine is used it must be immediately available for use in the resuscitation room.
Transducers

The transducer contains the piezoelectric element or crystal. This crystal produces the ultrasound beam which travels into the body and then reflects off the tissues back to the crystal.

The transducer translates one form of energy to another. An ultrasound transducer contains a piezoelectric crystal that can translate electrical signals into mechanical energy or mechanical energy into electrical signals.

The transducer uses a pulse echo technique to obtain an image. Initially, a sound wave is produced by electricity within the transducer and directed into the patient. The reflected sound waves are received by the transducer and converted into electrical signals, and an image can be created.

Types of transducers

Linear, sector and curved array are three formats of a transducer that determine the shape and field of view.
Linear array transducers produce rectangular images and offer the best overall image quality. Sector array transducers produce slice of pie shaped images and are optimal for examining larger organs from between the ribs.
Curved array transducers combine advantages of the sector and linear formats and are optimally used when the sonographic window is large.

High frequency = better resolution but less penetration (depth) (eg good for children & vascular access)
Low frequency = the opposite (eg good for obese patients)

Curved (A), linear (B), and sector (C) array transducers provide differing shapes in the ultrasound field-of-view.
US appearance of normal tissues

Simple fluid is black (lacking internal echoes). Fluids such as blood, urine and bile appear black or anechoic and exhibit posterior acoustic enhancement (see artefacts, below). This helps identify cystic structures (such as cysts, bladder and gallbladder) and tubular structures (ducts and vessels). See image below. The gallbladder (arrowed) is dark, well demarcated, and demonstrates posterior enhancement.

Some structures are grey.
Organ parenchyma and Examples include liver, kidney, uterus and heart. See image above: the liver (arrow) is grey.

Some structures are anisotropic.
This means that their appearance depends on the angle of the sound waves. Typically these are fibrous structures such as nerves, tendons and bones. These structures appear ‘grainy’, and if the transducer is perpendicular to the direction of the fibres then they are bright. The closer the transducer parallels the fibres, the darker they appear because less sound is reflected.
In the 2 images below, the same median nerve (arrowed) and surrounding forearm flexor muscles are viewed from slightly different transducer angles. On the left, the transducer is angled. On the right, the transducer is held perpendicular to the forearm.
Some structures are bright = echogenic (highly reflective) and cast posterior acoustic shadows because they reflect all or almost all of the sound wave (see artefacts, below). Examples include bone, metal implants, stones, bone and calcified vessels. The sound wave cannot penetrate beyond the surface so only the outer surface is visualised. See image below: the gallstones (arrowheads) within the gallbladder (arrow) are bright and cast a shadow.

Some structures vary because of their contents.
This is typical of the GI tract.
If the stomach is fluid filled it appears black.
If the stomach is gas filled it appears bright white, as the air ‘scatters’ the sound wave.
Some artefacts

Artefact
An artefact is echo information that does not correspond to anatomic information as it is positioned and reflected from within the patient. It may be:
  o Problematic- artefact may obscure detail and mimic pathology leading to diagnostic uncertainty or error.
  o Diagnostic- artefact such as acoustic shadowing is used in diagnosis of soft tissue foreign body and other conditions such as cholelithiasis.

Acoustic shadow
A very dense object that does not let ultrasound through casts an acoustic shadow. On the screen one sees the bright object with a black shadow distally. See image of gallstones above.

Acoustic enhancement
Occurs when sound passes through an anechoic structure. No echoes are reflected and so they are all available to pass through. More echoes are seen deep to the anechoic structure because more sound is available. See images of gallbladder above.
General tips to improve your image

- Use more GEL
- Lighting: as dark as possible
- The right patient position
- The right probe & preset
- The right orientation
- The right depth
- Overall gain
- Individual TGC/DGC sliders
- The right frequency (increase or decrease, but the general tip is to use as high a frequency as possible)
- Place focal zone at area of interest
- Narrow field of view
- Decrease depth of tissue of interest

The right patient position

- General principles:
  - A critically ill patient can’t move much: what you see is what you get
  - But don’t be afraid to move the patient if you can.

- Specifics:
  - Heart: left lateral improves image quality for cardiac imaging
  - IVC: moving the patient affects IVC caliber, so take this into account
  - Lungs: whatever the patient position, the same principles apply:
    - Air rises (a pneumothorax will be seen in the least dependent portions)
    - Fluid sinks (an effusion will be seen in the most dependent portions)
    - Consolidation tends to be more pronounced in the most dependent portions too
  - DVT:
    - Occlusive DVT will be seen whatever the patient position.
    - Images improve with:
      - Sitting or standing the patient
      - Valsalva manoeuvre

The right probe & preset: see later.
The right orientation

To orient yourself to the transducer, touch your finger to one side of it and observe which part of the screen records a signal. Choose the highest frequency that gives adequate penetration.
What the hell is…?

**Auto optimization**

- Lets you optimize the image based upon the actual B-Mode data.
- You can preset the amount of contrast enhancement (low medium or high) depending upon your preference.
- Then, with the touch of a button you can ‘pretty up’ the image
- The sonographers call this ‘the registrar button’
- BUT if you are in the wrong preset, you’ll get the wrong AO effect... eg if trying to image a heart using abdo preset.
- Remember the Garbage in, garbage out rule. The US machine is not telepathic- if you give it the wrong info (eg scan using the wrong preset) it will give you the wrong amount of contrast.

**Tissue harmonic imaging**

- As sound wave travels through tissue, the high pressure component of the wave travels more quickly than the rarefational component.
- This **distorts** the wave and generates higher frequency components (harmonics) deep in the tissues.
- eg 3MHz wave creates 6MHz, 12 MHz harmonics
- **Q: So what?**
- A: it turns out that aberrant/artefact signals are too weak to generate harmonic waves.
- Tissue harmonic imaging takes advantage of this: i.e. displays only the harmonic signals.
• THI images often display reduced noise and clutter. (That’s because aberrant/artefact signals are too weak to generate harmonic waves.
• NB harmonic beams are narrower than the original, so spatial resolution is improved and side lobes are reduced.

Confused? Think of it this way: Harmonics (THI) = ‘another great button’

• Just press it
• If it makes the image shittier, press again to turn it off. Easy!

NB Harmonic generation does not take place near the skin, so THI is no use there. Also no use in far field. So best for mid-depth images.

Read or Write Zoom?

Read Zoom = magnification function. This is the same effect as simply expanding a photo image- it doesn’t actually add data, so the resulting image won’t be better, just bigger.

By contrast, write zoom actually rewrites the image using more pixels, gives a much higher definition magnification. (less pixelly/boxy).

So, here’s a couple of rules when using the zoom function:
  First, use it! Always zoom your images to maximum (without pixellating the image) to make for easy reading and more accurate calliper placement when measuring small things (eg CBD)
  Second, zoom before you freeze, not vice versa. This ensures you are using ‘write zoom’.

Dynamic range a.k.a. compression

• Affects how much greyscale information is displayed on screen.
• More shades = more info. This is great for imaging the liver, but may be hard to interpret if the image becomes too soft.
• Less shades = less soft= more contrasty, useful for heart & blood vessels
• NB: watch out: fiddling with dynamic range can affect gain.

Line Density

• Optimises B-Mode frame rate or spatial resolution for the best possible image.
• A high line density is desirable for high resolution imaging of small parts (thyroid, breast testes…),
• However, a lower line density is useful in cardiac applications as it allows significantly higher frame rates.
• IE it’s a trade-off: the better the temporal resolution you want (eg great frame rates for crisp cardiac images) the lower the spatial resolution you have to put up with.
**Probe & presets for critical care US**

<table>
<thead>
<tr>
<th>PROBE</th>
<th>PRESET</th>
</tr>
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<tbody>
<tr>
<td><strong>LUNG</strong></td>
<td>Not the linear array (too much fine detail!)</td>
</tr>
<tr>
<td></td>
<td>• False neg PTX (movement)</td>
</tr>
<tr>
<td></td>
<td>• False pos PTX (pain)</td>
</tr>
<tr>
<td></td>
<td>The curved probe is best for image quality &amp; anatomy.</td>
</tr>
<tr>
<td></td>
<td>The phased array probe fits b/w ribs &amp; gets round the back.</td>
</tr>
<tr>
<td></td>
<td>• One with plenty of greyscale/dynamic range</td>
</tr>
<tr>
<td></td>
<td>• Abdo / FAST preset</td>
</tr>
<tr>
<td></td>
<td>• NOT cardiac preset</td>
</tr>
<tr>
<td></td>
<td>• Turn off the fancy filters: THI, compounding/MB etc- they make the artefacts harder to see</td>
</tr>
<tr>
<td><strong>IVC</strong></td>
<td>Curved probe is best:</td>
</tr>
<tr>
<td></td>
<td>• Image quality</td>
</tr>
<tr>
<td></td>
<td>• Anatomy</td>
</tr>
<tr>
<td></td>
<td>Phased array probe is OK if already switched on (eg for TTE)</td>
</tr>
<tr>
<td></td>
<td>Whatever preset you’re on is fine (Abdo / FAST / cardiac)</td>
</tr>
<tr>
<td><strong>Initial screening view heart</strong></td>
<td>Either probe is adequate (subcostal window is best if using the curved probe)</td>
</tr>
<tr>
<td></td>
<td>Whatever preset you’re on is fine (Abdo / FAST / cardiac)</td>
</tr>
<tr>
<td><strong>TTE</strong></td>
<td>Cardiac probe</td>
</tr>
<tr>
<td></td>
<td>• Phased array</td>
</tr>
<tr>
<td></td>
<td>• Sector = small footprint</td>
</tr>
<tr>
<td></td>
<td>Cardiac preset (image ‘round the wrong way’)</td>
</tr>
</tbody>
</table>
M-mode imaging = motion mode. What’s the point?

- ‘Surely 2D image is adequate’
- M-mode (motion mode) = movement along a single line of info against time
- Theoretically, a single line gives much better sensitivity & resolution

How to do it:
- ‘M’ button once & a line appears (NB need to press twice on some machines)
- Use touch pad / track ball to move the line to area of interest
- Press ‘M’ again to plot a graph of what that line sees versus time
- Stationary stuff = straight line
- Moving things = waves/ dots

* M mode pleural: seashore sign (see also Lung US section)

* M mode: LV contracting (see also Basic echocardiography section)
M-mode: pros & cons

PROS
- M-mode (motion mode) = movement along a single line of info against time
- Single line therefore much better sensitivity & resolution
- More accurate dimensions

CONS
- If angles wrong, measurements wrong!
- Easier to stuff up than B-mode
- IF IN DOUBT, USE B MODE
What about DOPPLER?

The Doppler effect

- Probe sends a sound wave of known frequency
- If it hits object moving towards probe, the returning sound wave is higher frequency
- If object moving away, the returning wave is lower frequency

Types of Doppler

Continuous wave [CW] Doppler

eg good old ‘ankle brachial index’ machine: very sensitive but won’t tell you what point the signal’s coming from!

Pulse wave [PW] Doppler

The machine sends ‘packets’ of sound waves & waits for each packet to return before sending the next packet. Less sensitive, but locates the site of the signal.

PW has 3 variations:
- Colour flow (CF)
- Spectral
- Power

Colour Flow [CF] Doppler

Remember the BART convention (Blue Away, Red Towards)
- Red = towards probe
- Blue = away

Problems with Doppler

Dependent on
- angle of insonation
- pulse repetition frequency
- operator skill & experience
For example, **aliasing** is a common problem:
As velocity increases, signal alters (eg in CF Doppler = lighter shade) until aliasing occurs = then **colour reversal** occurs [see fig below]

*Which way is the flow in this image?*
*Towards the probe (red)?*
*Away from the probe (blue)?*

*Is this turbulent flow (eg valve disease) or aliasing (due to normal high velocity jet from LVOT into AV)?*

**Top tip:**

In today’s course, we leave Doppler alone! It doesn’t add much to a resuscitation scan and has the potential to mislead.

Save it for the TTE courses.