The EACVI
Echo Handbook

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CHAPTER 1

Examination

1.1 How to set up the echo machine to optimize your examination

Preparing for the TTE examination

- Make sure the patient is comfortable/relaxed in a left decubitus position, with the left arm up to open up intercostal spaces and breathing quietly to minimize translation of the heart
- The echo-room should be:
  - darkened: avoid sunlight for optimal contrast
  - silent: auditory feedback allows optimizing Doppler sample positions
- A time-aligned ECG of good quality is mandatory for timing of cardiac events
- Select the appropriate probe according to the patient size
- Start with cardiac pre-settings (Fig. 1.1.1AB)

Important note:

The ultrasound machine needs maintenance for optimal performance

Fig. 1.1.1A Cardiac

Fig. 1.1.1B Abdominal

Acoustic power

Controls acoustic energy output

- More energy → better signal → better image quality (i.e. better signal-to-noise ratio: SNR) (Fig. 1.1.2AB, see also Box 1.1.1)
- Expressed in decibel [dB] relative to the maximal energy output available on the system (100% output = 0dB; 50% reduction = –6dB)
- Too much acoustic energy can result in tissue damage due to:
  - Heating: monitored through the 'thermal index' (TI should remain below 2)
  - Cavitation (i.e. formation of small gas bubbles with subsequent bubble collapse associated with high pressures/temperatures locally): monitored through the 'mechanical index' (MI should remain below 1.9)

Box 1.1.1 Recommendation

Although higher acoustic power increases SNR, it also increases the likelihood of bio-effects. Therefore, only increase transmit power if the default setting results in low SNR

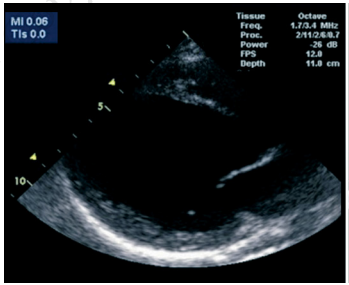


Fig. 1.1.2A Low acoustic

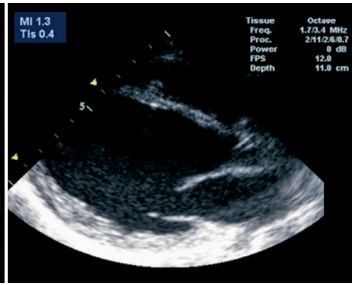


Fig. 1.1.2B High acoustic

Gain

Controls overall amplification of the echo signals

More gain

→ amplifies the echo signal

→ equally amplifies the noise

→ SNR remains identical! (Figs 1.1.3 and 1.1.4, **see also** Box 1.1.2)

Box 1.1.2 Recommendation

Use a gain setting that provides images with the desired brightness/appearance

Depth gain compensation

Depth-specific amplification of the echo signals to compensate for attenuation

→ Automatic: amplifies signals from deeper structures

→ Manual: allows correction of the automatic compensation (Figs 1.1.5ABC, see also Box 1.1.3)

Box 1.1.3 Recommendation

Start each examination with the sliders in their neutral (i.e. centre) position

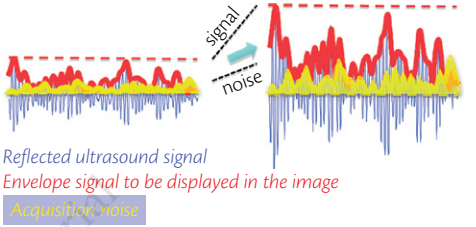


Fig. 1.1.3 Effect of gain SNR

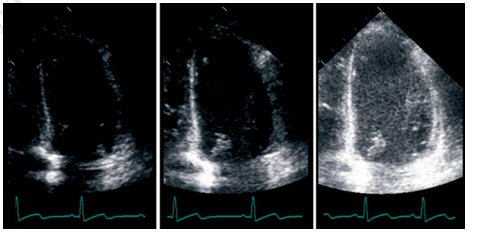


Fig. 1.1.4 Effects of increased gain on 2D image

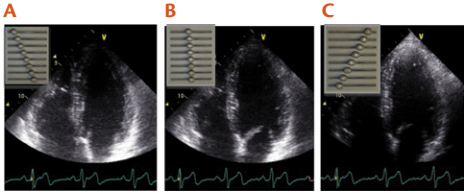


Fig. 1.1.5 Manual adjustment of depth gain settings. 5A: slider to the right, 5B: neutral, 5C: slider to the left

Transmit frequency

Controls transmit frequency of the transducer (see Box 1.1.4)

Lower frequency (Fig. 1.1.6)

→ Worse spatial resolution

→ Better penetration

Lowering transmit frequency will activate harmonic imaging (Fig.1.1.7)

→ Worse spatial resolution along the image line

→ Better SNR (i.e. less noise)

Box 1.1.4 Recommendation

- Use harmonic mode as default setting
- Keep the transmit frequency equal to the centre frequency of the probe unless:

1. Penetration is insufficient and no other probe is available
2. Switching between fundamental and harmonic imaging is required

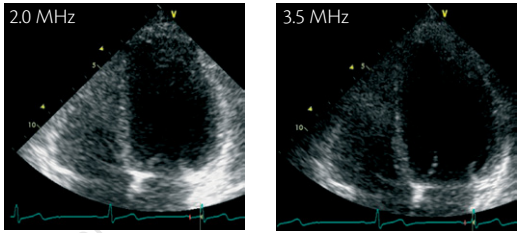


Fig. 1.1.6 Effects of changing transmit frequency

Note: Changing the frequency away from the centre frequency of the probe lowers spatial resolution

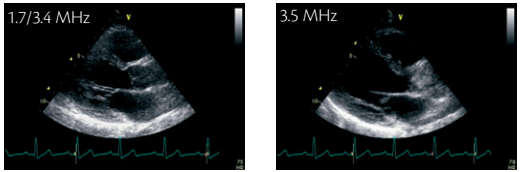


Fig. 1.1.7 Effects of lowering transmit frequency

Note: Harmonic imaging increases SNR but reduces intrinsic spatial resolution along the image line. This is particularly relevant when studying small/thin structures (i.e. valve leaflets)

Focal position

Controls the depth at which the ultrasonic (US) beam is focused

Around this region spatial (lateral) resolution is optimal (Fig. 1.1.8, see also Box 1.1.5)

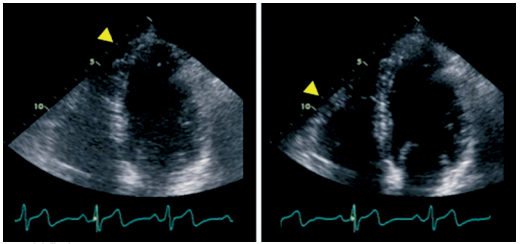
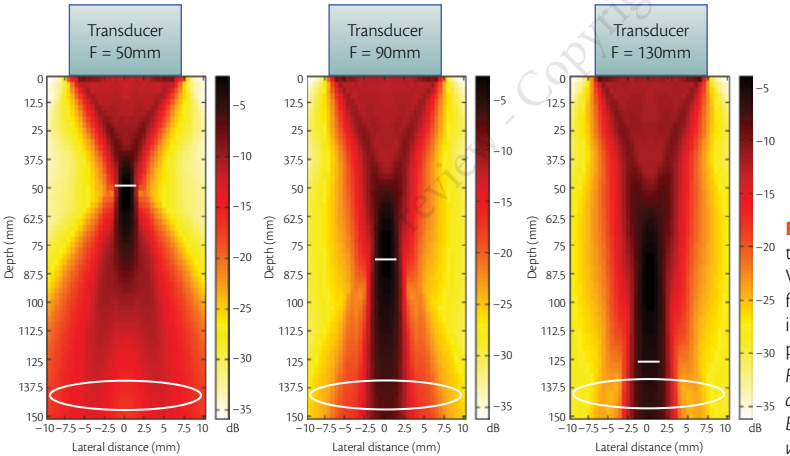


Fig. 1.1.8 Position of the focal point
Note: The position of the focal point is indicated alongside the sector image (arrow point)

Frame rate

Controls the trade-off between number of lines in a single frame and the number of frames created per second (see also Box 1.1.6)

Higher frame rate will result in less lines in the image and thus worse spatial (lateral) resolution (Fig. 1.1.10)



Box 1.1.5 Recommendation

Place the focal point *near the deepest structure of interest* (Fig. 1.1.9, right panel)

Fig. 1.1.9 Simulated pressure field of a cardiac transducer
White horizontal bar = beam width in focal zone when focus point at 50 mm (i.e. left panel) Mark the difference in beam width at larger depth with changing focal position (white circles)
Focus point deeper: less effective focusing, lateral resolution decreases
Beyond this focus point, beam widens, lateral resolution worsens

Box 1.1.6 Recommendation

Keep frame rate at its default value unless modifications are required for specific processing methodologies (i.e. speckle tracking analysis)

Continuous-wave and pulsed-wave Doppler

High-quality/reliable Doppler recordings require:

1. Proper alignment of the image (i.e. Doppler) line with the flow direction (< 20° off-axis) (Fig. 1.1.11, see also Box 1.1.7)

Box 1.1.7 Recommendation

Reposition and angulate the probe under colour Doppler guidance to obtain optimal alignment

2. Proper velocity scale (also referred to as Nyquist velocity/PRF) (Fig. 1.1.12AB)
   - Scale too low: aliasing
   - Scale too high: sub-optimal velocity resolution (i.e. smallest difference between two different velocities that can be measured is larger)

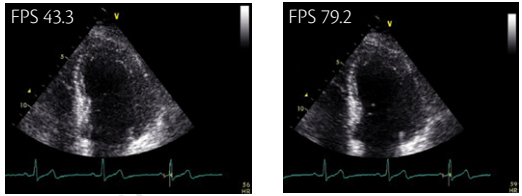


Fig. 1.1.10 Frame rate and spatial resolution

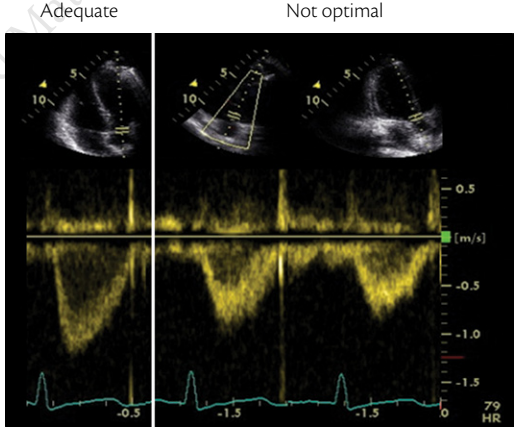


Fig. 1.1.11 Doppler recording

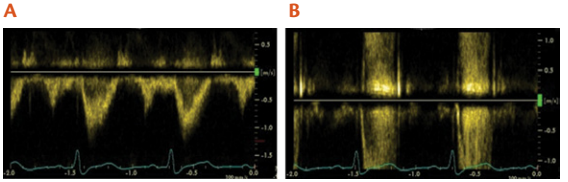


Fig. 1.1.12 Doppler velocity scale. A: Adequate, B: Too low (i.e. aliasing)

Continuous-wave and pulsed-wave Doppler

Sample position

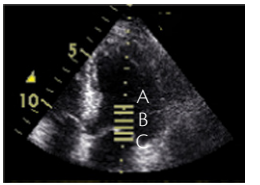
Controls the position of the sample volume (Fig. 1.1.13ABC, see also Box 1.1.8)

Box 1.1.8 Recommendation

Sample volume should be positioned at the tips of the (open) valve leaflets (for MV inflow)

Sample volume

Controls the size of the sample volume (Fig. 1.1.14ABC)



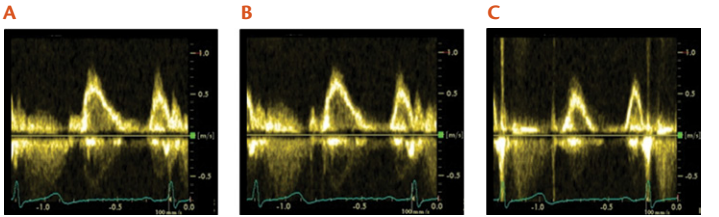


Fig. 1.1.13 Sample position. A: Too high, B: Appropriate C: Too low

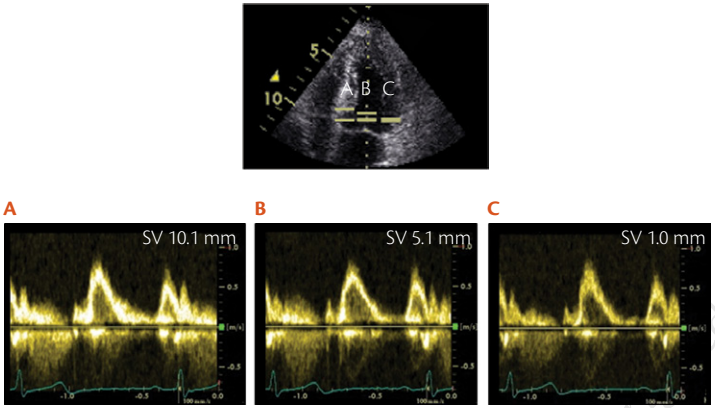


Fig. 1.1.14 Sample size. A: Too large, B: Appropriate, C: Too small
- Small sample volume: good spatial resolution at lower velocity resolution
- Large sample volume: good velocity resolution at lower spatial resolution

Continuous-wave and pulsed-wave Doppler: settings

Wall filter

Controls the threshold for velocities displayed in the velocity spectrum (Fig. 1.1.15ABC, Box 1.1.9)

Box 1.1.9 Recommendation

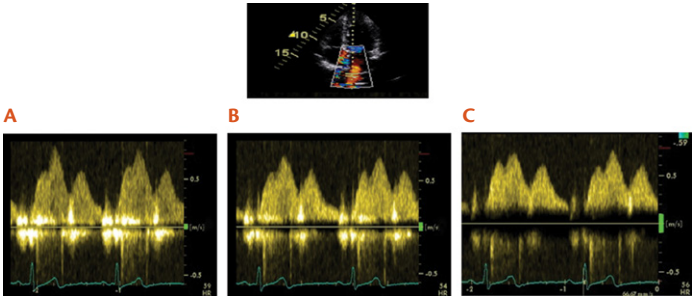
Wall filter should be as low as possible while avoiding pollution by myocardial velocities

Sweep speed

Controls the refresh rate of the velocity spectrum (Fig. 1.1.16AB, Box 1.1.10)

Box 1.1.10 Recommendation

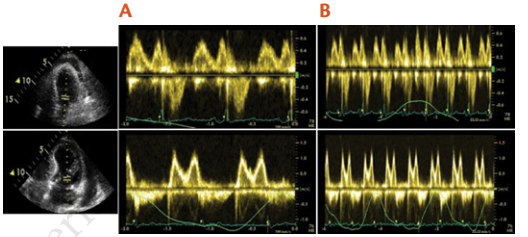
Always use a sweep speed of 100 mm/s unless looking for inter-beat variations



Strong (slow) myocardial velocities pollute the spectrum

Slower-moving blood velocities are no longer displayed

Fig. 1.1.15 Wall filter. A: Too low, B: Appropriate, C: Too high



High velocity scale to look at intra-beat velocity changes

Low velocity scale to look at inter-beat (i.e. respiratory) velocity changes

Fig. 1.1.16 Sweep speed. A: 100 mm/s, B: 33 mm/s

Colour-flow mapping

Velocity scale

Controls the range of velocities displayed in the colour box (Fig. 1.1.17, Box 1.1.11)

Box 1.1.11 Recommendation

Velocity scale should be as low as possible without aliasing

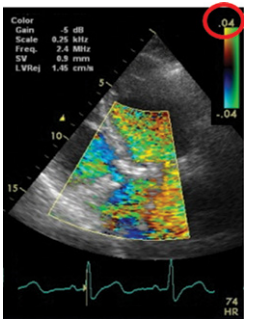


Fig. 1.1.17 Velocity scale

Aliasing

- Blue: motion away from transducer
- Red: motion towards the transducer
- Green: velocity out of range (i.e. aliasing)/ large spatial variance (i.e. turbulence)

Colour gain

Controls amplification of the colour Doppler signals (see Box 1.1.12)

Box 1.1.12 Recommendation
Should be as high as possible, without noise appearance

Size of colour box

Directly impacts frame rate (Fig. 1.1.18AB, Box 1.1.13)

Box 1.1.13 Recommendation
Colour box should be as small as possible, to optimize temporal and spatial resolution

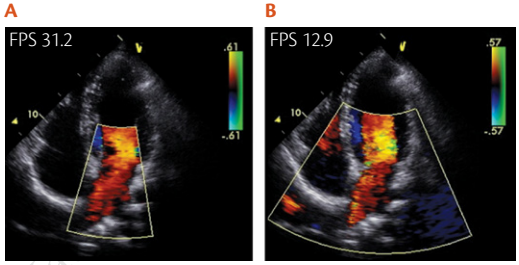
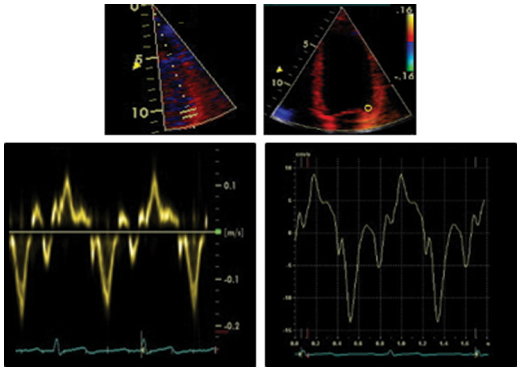


Fig. 1.1.18 Colour box size. A: Adequate, B: Not optimal

Advanced techniques

Myocardial velocity imaging (MVI) (Fig. 1.1.19)

1. Proper alignment of the image line with the wall motion direction
2. Proper velocity scale (Nyquist velocity/PRF)
3. Small sector angles for higher frame rates (optimal > 115 fps)



PW Doppler *Colour Doppler*

Fig. 1.1.19 Myocardial velocity imaging

4. Adjust sample position, sample size, wall filter, and sweep speed
5. High-quality ECG required for optimal timings all apply for myocardial PW and colour Doppler analyses *(as for blood pool Doppler)*

Speckle tracking—2D strain (rate) imaging (Fig. 1.1.20)

1. Optimize gain settings and focus position
2. Centre the region of interest
3. Adjust depth and region of interest size for optimal spatial resolution *(MV annulus at the bottom of the image for LV regional function analysis)*
4. Adjust frame rates since specific analysis software often requires specific frame rate settings (optimal 50–90 fps)
5. High-quality ECG required for automated tracking

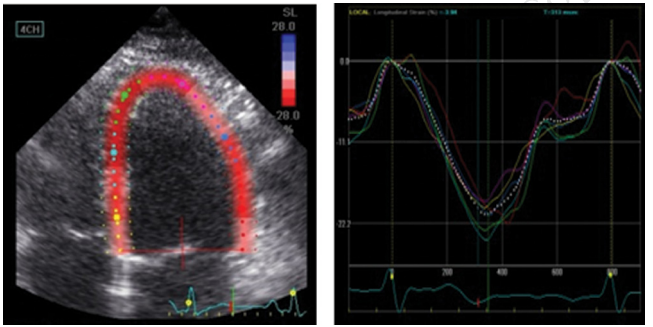


Fig. 1.1.20 2D–speckle tracking imaging

3D imaging (Fig. 1.1.21)

1. Transducer position: a good acoustic window is essential for optimal 3D visualization (difficult because of larger probe size)
2. Use 2D guidance for centring of the region of interest
3. Image acquisition during breath hold or quiet respiration
4. Adjust volume size to optimize volume rate (real time vs stitched images for post-processing)
5. Adjust gain and avoid drop-out artefacts
6. Crop, translate, and rotate the 3D volume to visualize the structure of interest

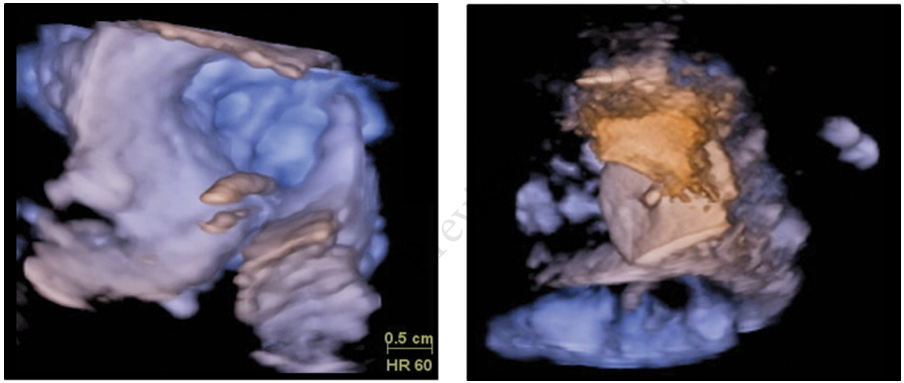


Fig. 1.1.21 3D imaging