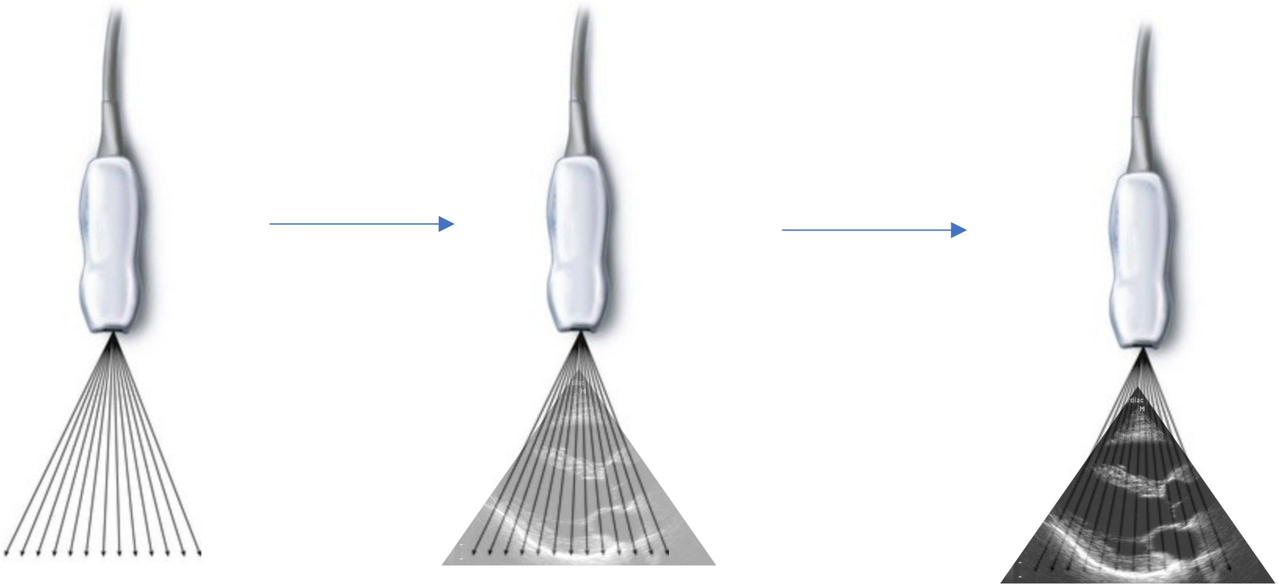
Doppler and scanning modes

1. 2D ultrasound

- Image is built from a series of scan lines (ultrasound pulses) side by side
    - Probe produces ultrasound pulse and then waits for reflected ultrasound to be received
        - Once this occurs an image can be generated along this line
    - Subsequently sends next ultrasound pulse in a slightly different direction to the previous one
        - Essentially sweeps across the heart 20-30 times per second ('frames' per second)
    - Reducing depth (ultrasound waits less time to receive) or sector width (sends out fewer ultrasound pulses) will reduce the time taken to produce one frame
        - This therefore increases the number of frames produced per second (frame rate) and temporal resolution

- Useful for visual assessment of structures and regional wall motion abnormalities



A diagram to show how individual ultrasound scan lines are combined to create a 2D PLAX image

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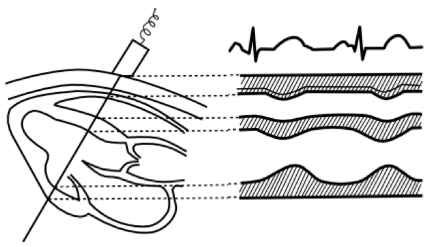
2. M-mode scanning

- Motion mode
- M-mode image generated shows movement along a single sampling line within the 2D echo image over time
    - I.e Movement = *y*-axis, time = *x*-axis



- Useful for visualising:
    - Rapid motion (narrow field of view allows higher sampling rate)
    - Measurement of cardiac dimensions

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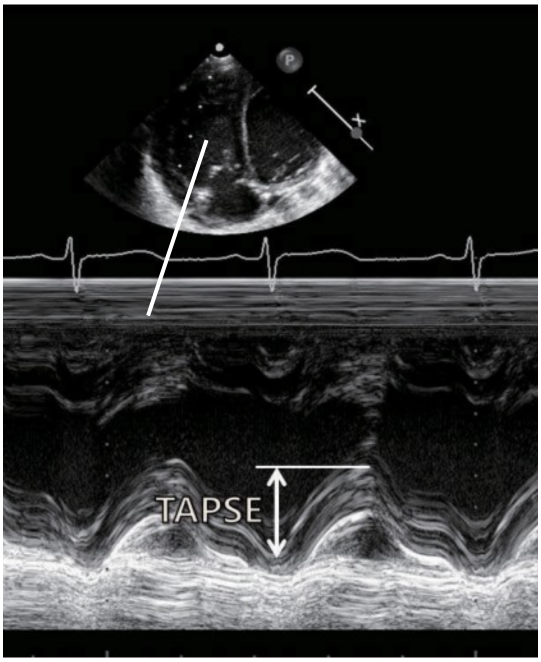
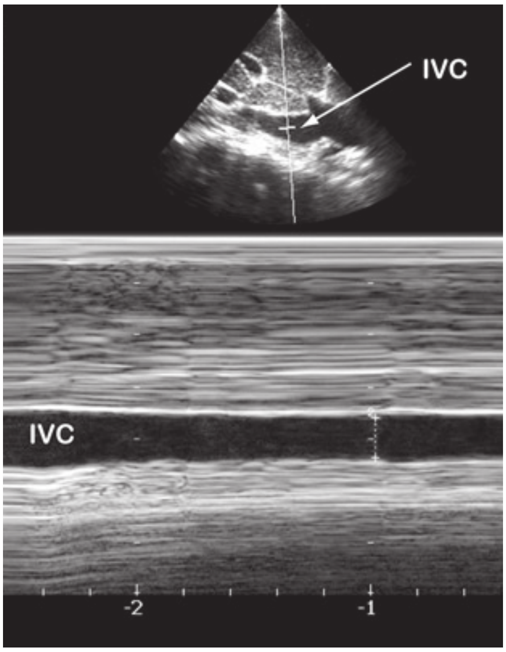
Example uses:

TAPSE – Tricuspid annular plane systolic excursion (normal >1.6 cm) - Sampling line through tricuspid annulus	IVC diameter respiratory variation (normal 1-2cm with respiratory variation) - Sampling line perpendicular to IVC, between hepatic vein and RA





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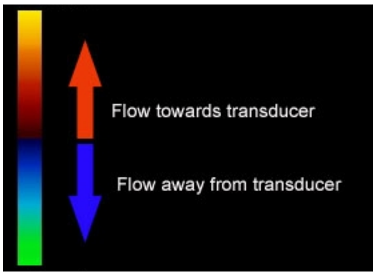
3. Colour flow mode (CFM)

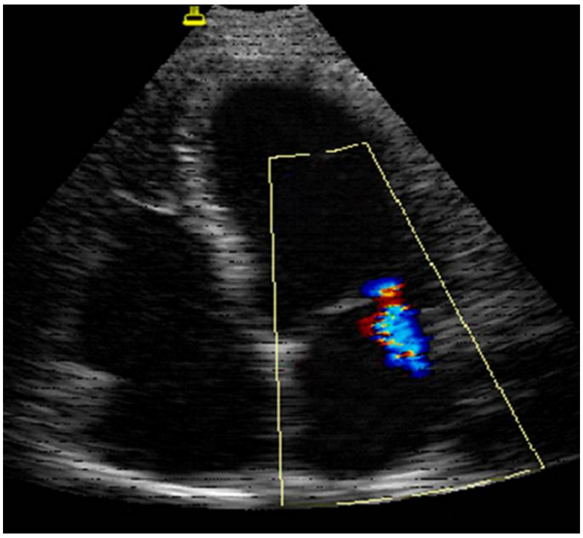
- Colour flow mode
    - Relies on Doppler shift to generate image
- Colours associated with direction of travel of blood relative to probe
    - '**BART**' = Blue Away, Red Towards
    - Ultrasound strikes blood moving away and frequency decreases → **BLUE**
    - If blood moving towards ultrasound probe – frequency increases → **RED**
- Velocity indicated by hue of red/blue colour



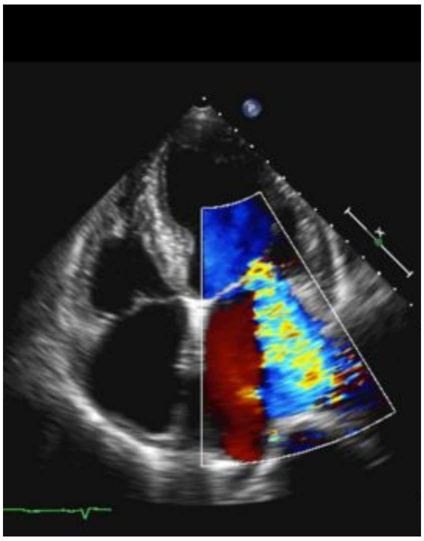
- It is crucial to alter the size and location of the CFM box to encompass all areas of flow being assessed (e.g the entire LA when assessing MR)

- Useful for assessing pattern of flow within vessels/cardiac chambers, particularly:
    - Valvular regurgitation
    - Septal defects

CFM assessment of mitral valve with *trivial* MR



CFM assessment of mitral valve with *severe* MR



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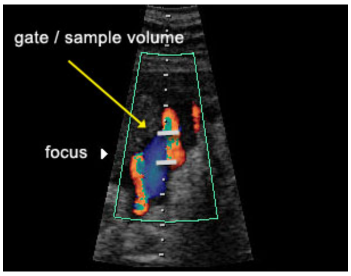
4. Pulsed wave doppler

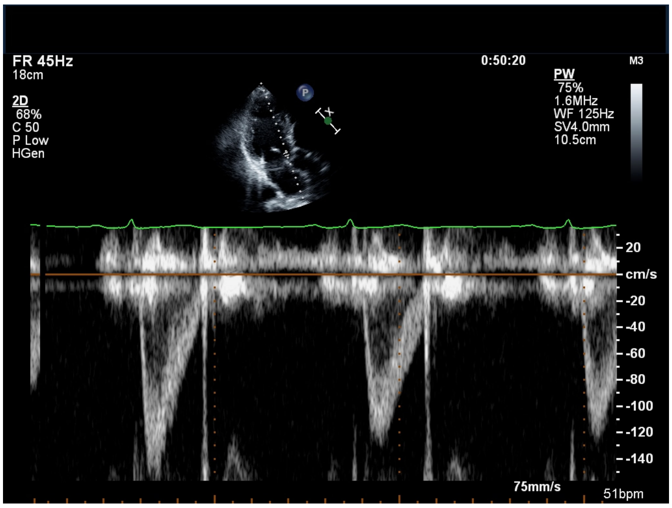
- When selected, produces sampling line with a sample volume or **'doppler gate'** - this MUST be aligned <20^0 to blood flow (i.e sampling line parallel to flow)
    - Ultrasound machine ignores everything outside of that gate
    - Major advantage – it is **site specific**



- PWD also relies on Doppler shift to produce an image
    - Probe produces short bursts of ultrasound
    - Frequency of returning ultrasound is compared to that emitted and calculates velocity of echogenic material within Doppler gate
- A new image is produced that represents the velocity of blood within the Doppler gate over time
    - I.e velocity of blood within Doppler gate = *y*-axis, time = *x*-axis
        - Flow towards probe – positive deflection (up) from baseline
        - Flow away from probe – negative deflection

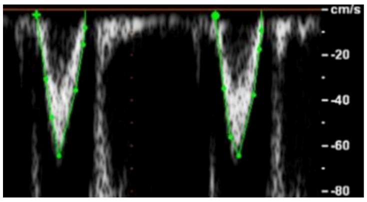
- Major drawback = inability to correctly assess higher velocities due to **'aliasing'** phenomenon with pulsed ultrasound
    - Therefore, useful for measuring slower velocities at a specified depth
    - Cannot be used to assess high velocity jets

PWD of the LVOT, showing velocity of blood within the Doppler gate over time



Use of PWD and velocity-time integral (VTI)

To calculate the flow volume of pulsatile blood flow requires calculation of the 'velocity-time integral' = the area under the curve ('spectral envelope') produced during PWD



- VTI represents the stroke distance in cm – the distance travelled by a column of blood in the sampled region in one flow period
    - To calculate flow volume this must then be multiplied by the cross-sectional area of the same region

- Cross-sectional area is calculated using the equation:
    - CSA = 0.785 x $(\text{diameter})^2$

Therefore:

Flow volume = CSA x VTI

LVOT PWD can therefore be used to calculate **stroke volume** & **cardiac output**

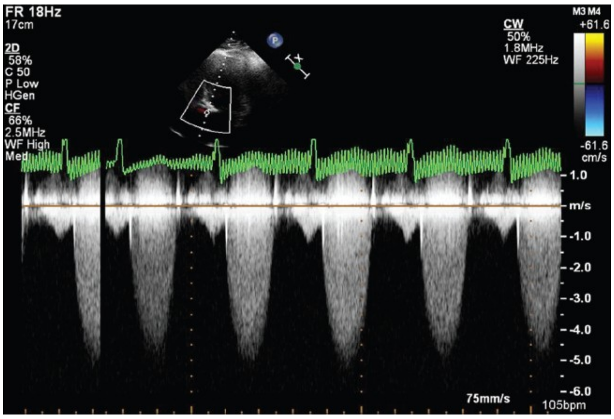
1. Diameter of LVOT measured in PLAX, just proximal to cusps → calculate CSA
2. In A5Ch view use PW Doppler to measure VTI of outflow in LVOT at the same level as the diameter measurement was taken (VTI_{LVOT})
3. SV = CSA_{LVOT} x VTI_{LVOT} in ml/beat
4. CO = SV x HR /1000 in L/min

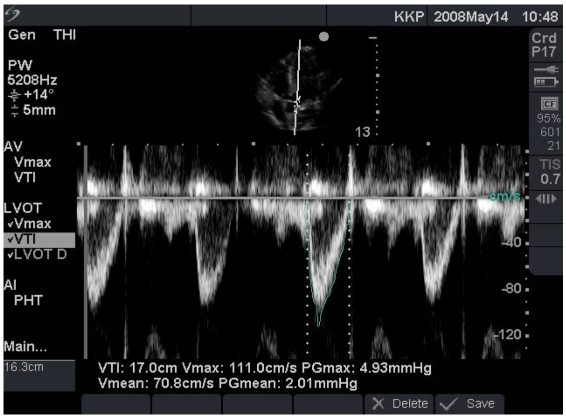
5. Continuous wave doppler

- Ultrasound signals are continuously transmitted (unlike all other modalities mentioned) by one piezoelectric crystal
    - Continuously received by a second crystal
- Every velocity along the sampling line is recorded (unlike PWD – this only occurs within the doppler gate), therefore the CWD trace appears filled in
    - Again, the sampling line must be aligned <20^0 to direction of flow
    - Very high velocities may be recorded
    - However, unable to identify where on the sampling line the velocity was detected

CWD records every velocity present along the sampling line and the resulting trace is 'filled in'

PWD records the velocity at a specific point along the sampling line and the resulting trace is hollow





- CWD is used for measuring:
    - High velocity jets
        - TR Vmax – subsequently used to calculate pulmonary artery systolic pressure if RA pressure is known (i.e CVP line in situ)
        - Peak velocity through AV
    - Valve gradients
        - Mean gradient through AV

Measurement of pulmonary artery pressure using TR V_{max}:

This makes the assumption that RV systolic pressure (RVSP) = pulmonary artery systolic pressure (PASP)

1. Using CWD assess peak velocity of regurgitant flow through tricuspid valve (TR V_{max}) in m/s (PSAX aortic valve level view/ modified A4Ch/ parasternal RV inflow view)
2. This regurgitation reflects the pressure gradient between RV systolic pressure and RA pressure – this is calculated using the simplified Bernoulli equation:
    - RVSP – RAP = 4 x (TR V_{max})^2
    - RVSP = 4 x (TR V_{max})^2 + RAP
    - PASP = 4 x (TR V_{max})^2 + RAP

For more information and resources visit:

www.criticalcareecho.com

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