Certificate in Clinician Performed Ultrasound (CCPU)

Neonatal Cardiac Ultrasound

Style Guide

Australasian Society for Ultrasound in Medicine
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Contents

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Purpose of document.

This document has been put together to offer some guidance towards a minimal standard of neonatal point of care ultrasound required to obtain a CCPU. It is an adaptation of a standardised paediatric full anatomical study (in accordance with Cardiac scanning protocols nationwide and internationally). This document outlines general principles applicable to all paediatric echocardiographic scanning. Not all point of care ultrasounds will require all these views, though at some point they will need to be obtained to exclude any major congenital anomalies. It is also expected that where congenital anomalies or abnormalities of function are found additional views may be necessary.

This document will also form the basis of a calibrated marking guide for those assessing scans for CCPU. Submitted scans will be assessed against these criteria. In addition to producing the images the candidate will be expected to make appropriate inferences in relation to the clinical setting and if necessary to make appropriate referrals.

Scope of neonatal point of care echo.

The relationship between neonatologist performing echo and paediatric cardiologists has matured over the last 20 or so years. In most centres there is a well-established working relationship with ground rules that have evolved as individuals have worked together. This situation is to be encouraged. While congenital heart disease is clearly the domain of the paediatric cardiologist a neonatal functional echo is uninterpretable without the simultaneous exclusion of underlying congenital defects. It is therefore imperative that a neonatologist performing an echo can recognise the common presentations of congenital heart disease and communicate any findings with their paediatric cardiology colleagues. Neonatal echo skills therefore need to be sufficient to produce a scan that visualises all the main cardiac structures, their functional integrity and relationship with one another. The standard for CCPU should be to produce a scan that a paediatric cardiologist can interpret.

This guide seeks to provide a minimum standard for such a scan.

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Basic principles

Specific settings described in this document (probe selection, default settings) refer to use with Philips IE33 or Epiq machines, that are widely used in Australian cardiac and neonatal departments. Other echo machines include GE E95 or Vivid I or Q machines, or equivalent Toshiba or Hitachi machines are commonly used in Asia.

- ECG tracing is strongly recommended – different machines are calibrated differently. Usual standard is retrospective capture of 2-4 beat loops. May alternatively choose 2-second timed loops.

- Probe selection –
    - Neonates (term 3.5kg): S8 probe for subcostal imaging, S12 for parasternal and apical imaging. Either probe may be suitable for suprasternal views for the aortic arch, suggest trying the S12 probe first, then switching to S8 if more penetration is required to obtain optimal image.
    - Pre-term neonates: Usually S12 probe for all imaging

- Default setting
    - General (GEN) which is sufficient for most neonates. Harmonics is usually off.
    - If the image is suboptimal despite the 'iScan' setting, then should try other machine settings such as resonance (RES) or Harmonics (HGEN). Penetration (PEN) setting rarely required, suggest using a lower frequency probe if image quality remains poor.

- Optimisation
    - Essential to take the time to optimise every image before acquisition. Much less likely to miss pathology if this step is taken.
    - Optimise 2D settings such as depth, sector width, move focus position to the area of interest.
    - Optimise colour settings by narrowing the colour box to the area of interest, choosing an appropriate colour scale for different vessels and sweeps (see below).
    - Aim for the highest frame rate as possible

- Colour scales
    - Use as a guide only, different neonates may behave differently.
    - The optimal colour scale (Nyquist limit) is one that allows for interrogation of the vessel/structure without colour aliasing (scale too low) or insufficient colour (scale too high, eg may miss a VSD on Day 1 if RV pressures are elevated)
    - Atrial septum, systemic veins ~40-60cm/sec
    - Pulmonary veins ~40-60cm/sec
    - VSD sweeps ~50-70cm/sec
    - AV valves ~60-80cm/sec
    - VA valves, aorta, pulmonary arteries ~80-120cm/sec

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Imaging Windows

The standard approach to imaging is as follows –

- Subcostal views – long axis and short axis (neonates don't always tolerate these views, may be left till last)
- Parasternal views – long axis (PLAX) and short axis (PSAX)
- Apical views – 4 chamber (a4c), 5 chamber (a5c)
- High Parasternal views
- Suprasternal views

Basic sequence is to capture

- 2D cine image first to define anatomy, followed by
- Colour Doppler to assess directions of blood flow, then
- Spectral Doppler (Continuous or Pulse wave) to measure velocities, then
- Measure vessels if required

- CW or PW Doppler beam should be aligned as closely as possible to the colour jet (low angle of insonation) so as not to underestimate gradients
- Angle correct is not necessary as alignment of the vessel to the Doppler beam is possible in most cases – should aim to find the best aligned imaging window

Other tips

- Ensure an open line of communication with the bedside nurse – he/she is watching the patient whilst you are watching the screen, so stop scanning if told! Be cognisant of alarms and your surroundings as you may be making the neonate unstable.

- Sucrose may be helpful if the neonate is allowed.

- It is generally helpful to stick to a scanning structure so as to not miss images, however it may be helpful/recommended to scan the primary structures of interest first (eg if the question is ?PDA, then perform a ductal cut as your first image), in case your patient gets too unsettled or unstable later on. You can always resume your 'flow' after the pertinent images are done.

- If the neonate is too unsettled or unstable, do not keep scanning! It is better (both for the patient and you) to come back another time to complete the study, than to keep persevering.

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Style guide summary

Long axis LV views	▪ 2d view ▪ Mitral and LVOT colour views ▪ LA:Ao ▪ Contractility
Long axis TV views	▪ 2d view ▪ TV colour ▪ TV CW
Long axis MPA/ PV	▪ 2d ▪ colour ▪ PW
Short axis AV	▪ 2d ▪ Colour
Short axis MPA	▪ 2d ▪ Colour
Short axis LV	▪ 2d at MV ▪ 2d at papillary muscles ▪ 2d at apex ▪ colour sweep
High parasternal views	▪ Branch PAs - 2d, Colour, PW ▪ Pulmonary veins ('Crab' view) - 2d , Colour
Suprasternal views	▪ Ao arch and great vessels - 2d, Colour ▪ Descending Ao arch – Colour, PW ▪ SVC Diameter *(Optional and may often leave until the end)* ▪ DA cut - 2d/colour, PW
Apical 4 and 5 chamber views	▪ 2d ▪ M-Mode TAPSE *(Optional)* ▪ MV – Colour, PW ▪ TV – Colour, PW ▪ Septal views – colour sweep ▪ LVOT – Colour, PW (if good angle)
Subcostal views	▪ Atrial septum - 2d, Colour ▪ SVC – Colour, PV
Transverse and Longitudinal abdominal views	▪ Situs ▪ IVC / hepatic veins ▪ Abdominal Ao

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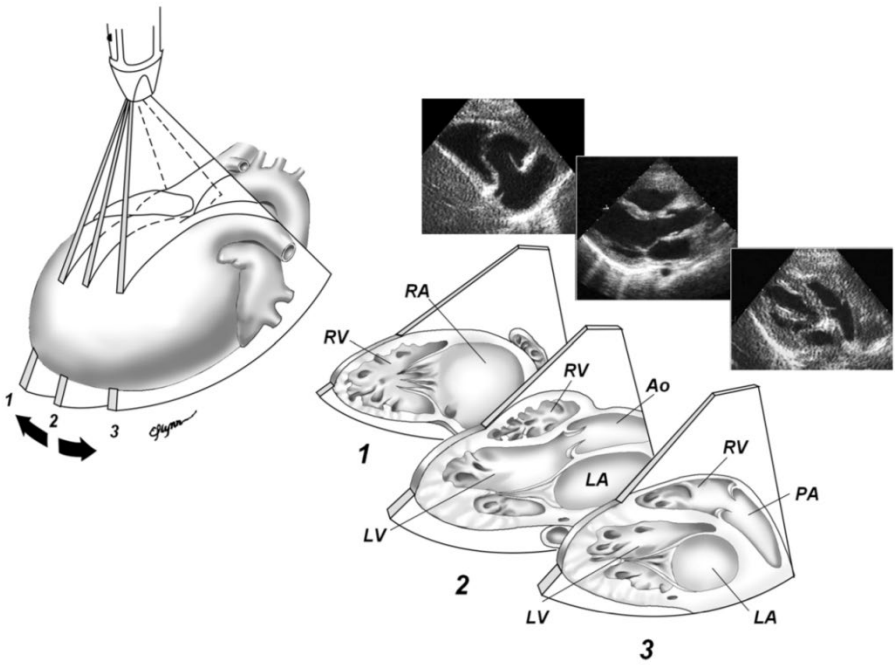
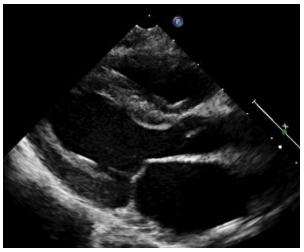
Long axis views



Long axis LV views

Long axis LV 2D

It is common but not essential for a neonatal scan to commence with parasternal long axis views. Most neonates are less likely to tolerate subcostal views, and these are often best left to the end of the scan. Much can be learned from the standard LV long axis view including an assessment of preload from the relative LA size, and an overall impression of left ventricular contractility and of the LV muscle bulk. The MV and AV should be seen and valve leaflets observed.



Technical tips. *Care should be taken to obtain as full a view of the left ventricle as possible, this may require rotating the probe anticlockwise, more horizontally across the chest, in very premature infants. View should clearly show the LA, LV, and LV outflow tract and their relationship to one another. The mitral valve and its movement during the cardiac cycle should be visible.*

Long axis LV views, colour mapping

Colour mapping should follow the natural course of blood flow through the left side of the heart. Several clips will be required to capture this.

I. Through floor of LA to show filling from pulmonary veins
   Technical tips. *Remember to reduce 'scale' to venous levels, generally 40m- 60 cmsec^{-1}.*
II. Mitral filling, assess both filling and any regurgitation. In general, mitral filling may be better assessed from an apical four chamber window.
III. LV outflow, assess blood movement across AV and into the LVOT.
IV. Inspect ventricular septum along its length for VSD.
   Technical tips. *Beware of confusing a TR inflow jet with a membranous VSD.*

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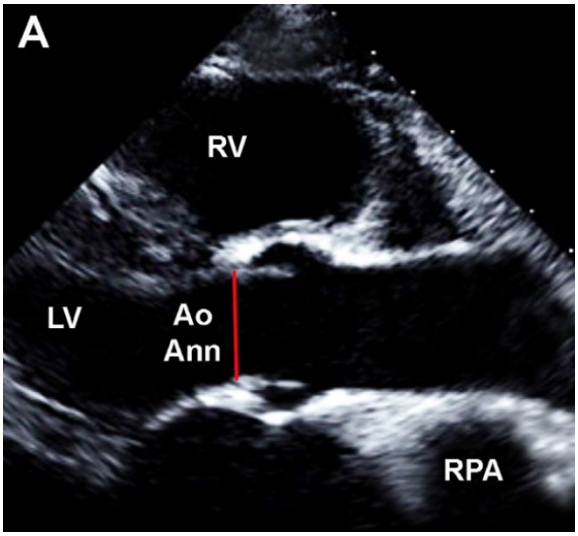
Video 1 LAX LV view.

Long axis LV LA:Ao

Assessment of LA size in relation to Ao root. Can be a useful indicator of preload and possible need for volume or an indicator of increased blood flow in a L to R shunt such as DA. An M mode image through the Ao annulus and LA should be recorded and measured.



Lopez L, Colan SD, Frommelt PC, et al. Recommendations for quantification methods during the performance of a pediatric echocardiogram: a report from the Pediatric Measurements Writing Group of the American Society of Echocardiography Pediatric and Congenital Heart Disease Council. *J Am Soc Echocardiogr* 2010;23(5):465-95; quiz 576-7. doi: 10.1016/j.echo.2010.03.019

Technical tips. *The Image needs to be carefully aligned such that the line of M mode interrogation passes through the centre of the aortic annulus at 90 degrees to the outflow tract. Obtaining a signal from the closed Ao valve in the centre of the annulus can help confirm this. Measurement of the Ao annulus at this point may be used to later calculate LV output, remember that any errors introduced at this stage will be squared in calculating output. It is preferable to measure the Ao annulus diameter directly from a 2d image, hinge point to hinge point.*

Long axis LV contractility

Assessment of LV contractility at level of tips of mitral valve. This measurement can also be made in short axis at the basal level below mitral valve leaflet tips. An M Mode line needs to be dropped perpendicular to the orientation of the LV and through the tips of the closed mitral valve. The internal end-diastolic and systolic dimensions are used to calculate fractional shortening (FS). Measurement of ejection fraction in neonates is unreliable due to asymmetrical LV morphology and should not be used.

Technical tips. *Care needs to be taken to orientate the image so that the M mode line of interrogation passes at 90^0 to the LV. Failure to do this will give erroneous measurements. Always ensure measurements are congruous with the 2D image.*

Video 2 LAX measure

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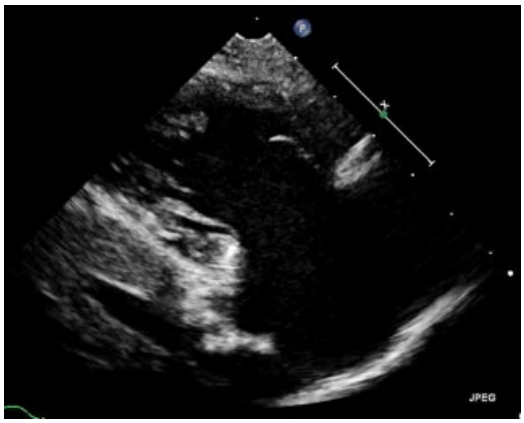
Long axis TV view

Long axis TV view 2D



View showing RV inflow across TV. Should show morphology and movement of TV and relative volume of RA.

Long axis TV colour

Apply colour mapping to the above view to show flow of blood into RV, search for any evidence of regurgitation across TV.

> ***Technical tips***. *The tricuspid regurgitant jet maybe forked and multidirectional you may need to dynamically view to pick the maximum jet.*

Long axis CW across TV

If a TR jet is demonstrated on the colour mapping a CW line of interrogation should be placed in the area of maximal jet and an image of the velocity pattern recorded. The maximal jet velocity should be measured. If the TR jet is incomplete, RV systolic pressures may be underestimated.

> ***Technical tips***. *CW is preferred over PW as the maximal velocity may exceed the Nyquist limit.*
>
> Video 3 LAX TV

Long axis MPA / PV

Long axis MPA 2D

2D Image of the right ventricular outflow tract that should be as near to vertically orientated in the centre of the screen as a possible. The pulmonary valve should be clearly visible and the anatomy and movement of the valve assessable.

Long axis PV diameter
If measuring RV output we require an accurate assessment of the PV annulus diameter, this may be assessed either from this long axis view or from a short axis view (see later). In the long axis view the hinge points of the PV leaflets need to be clearly visible and the maximum distance between them in systole measured.

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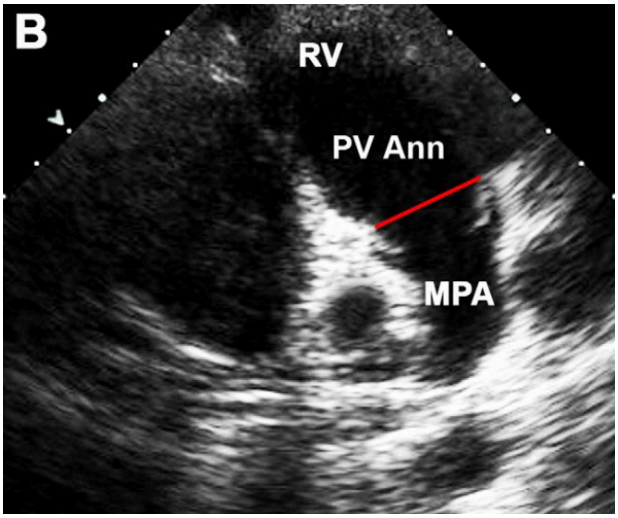

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***Technical tips**. Take care to obtain the maximal width of the pulmonary tract to ensure a diameter and not a cord is measured. Any errors in measurement will be squared when calculating RVOT*

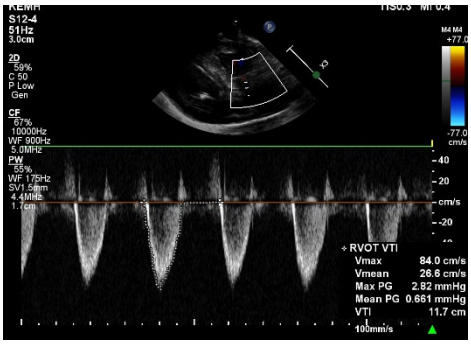
Long axis MPA colour mapping

Place a colour Doppler window over the PV and MPA. Flow across the valve and into the MPA should be clearly seen. Inspect for PV regurgitation or stenosis and any evidence of reversed ductal flow in the MPA.

***Technical tips**. If a DA is suspected a better view can be obtained by angling the probe shine the beam more anteriorly (into the throat).*

Long axis MPA PW

Record a PW trace in MPA. Low systolic velocities are indicative of a low RV output (< 0.4 $msec^{-1}$). High diastolic velocities are indicative of a DA. If PS is suspected from previous images the velocities across the valve should be interrogated with CW.



***Technical tips.** Place the PW gate at the tips of the PV at the centre of the MPA taking care to minimise the angle of insonation by aligning with MPA. VTI is only valid if the waveforms are laminar, RVOT outflow should not be measured if there is a DA.*

Video 4 LAX MPA

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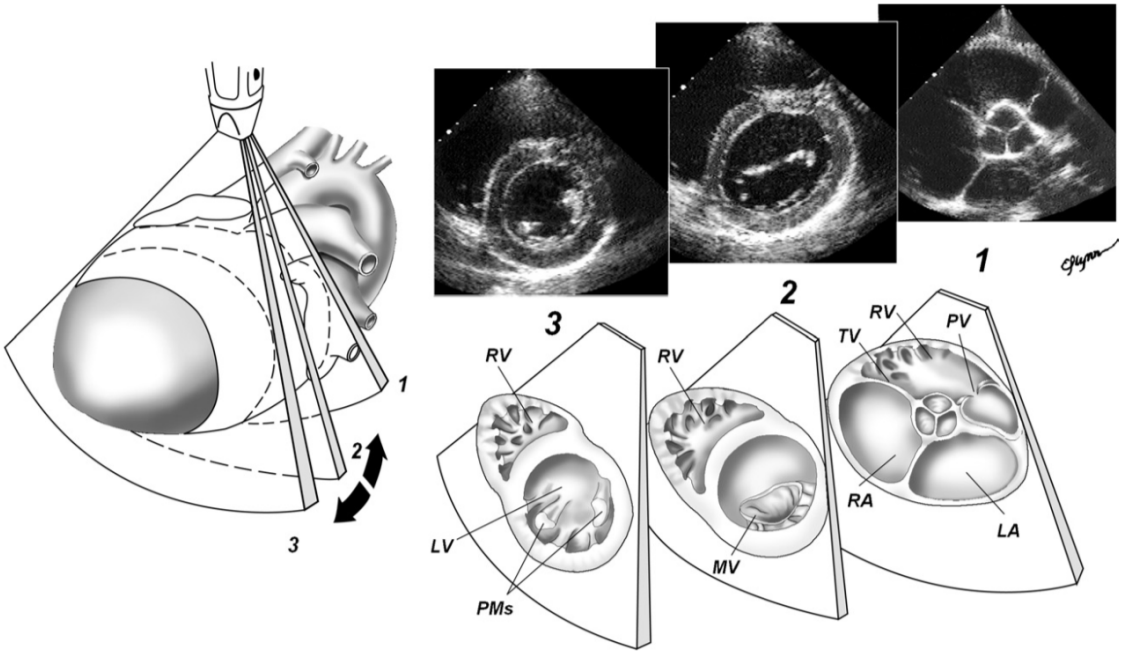
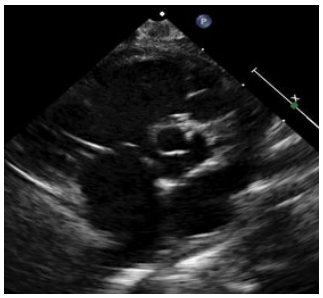
Short axis views



Short axis AV



Short axis view with the AV en-face showing the valve leaflets as the Mercedes-Benz sign. Need to observe the shape and movement of the cusps, if possible include origin of both coronary arteries. The relationship between the AV and PV should be demonstrated.

> ***Technical tips.*** *In very preterm infants the heart will be almost horizontal across the chest and the probe will need to rotate anticlockwise (notch towards mid left clavicle). It may not be possible to see the Mercedes-Benz sign and the origin of the coronaries in the same plane.*

Short axis MPA

Aiming the beam more towards the right shoulder will bring the MPA into view. This should wrap around the aorta. If the window is favourable the PV annulus may be measured from this window. Clockwise rotation should bring the bifurcation of the MPA into view.

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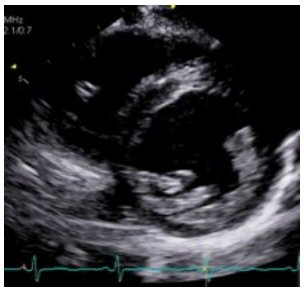
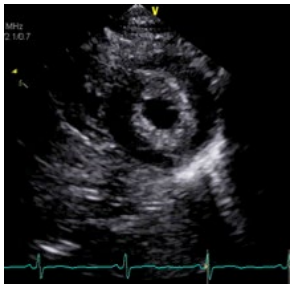
Short axis MPA, colour map.

Add colour to demonstrate flow in MPA and if possible down to level of DA.

Technical tips. *If the DA is patent a milking stool view may be seen with three branches arising from the MPA. It may be difficult to appreciate a DA in this view if there is pulmonary hypertension and the colour flow is blue.*

Short axis LV views.





Sweep down though the LV in short axis. Note the shape of the LV, muscle bulk and contractility. Either record an extended sweep or record tracings at the level of the mitral valve (fish mouth), level of papillary muscles and at the apex. Assess if the interventricular septum is rounded or flattened. Interventricular septal flattening in systole alone suggests the RV pressure is up to ½ systemic levels, septal flattening in diastole suggests volume loading. If the septum is flattened in both systole and diastole then RV systolic pressures are estimated to be at least ½ systemic levels.

> ***Technical tips.*** *Take care to ensure the LV remains in short axis. It is impossible to assess shape or contractility unless you are in a true short axis plane.*

Short axis LV views, colour map.

Ideally we need a sweep from LV apex to base in a colour map to look for a VSD. An alternative, after performing a full sweep, is to take short colour images at the level of the aortic valve, level of the papillary muscles and towards the apex. Muscular VSD's may be anterior, posterior, mid or apical, hence the entire septum should be interrogated fully from base to apex. Perimembranous VSDs are in direct continuity with the tricuspid and aortic valves and are seen at the aortic valve level, at approximately the 10:00 o'clock position.

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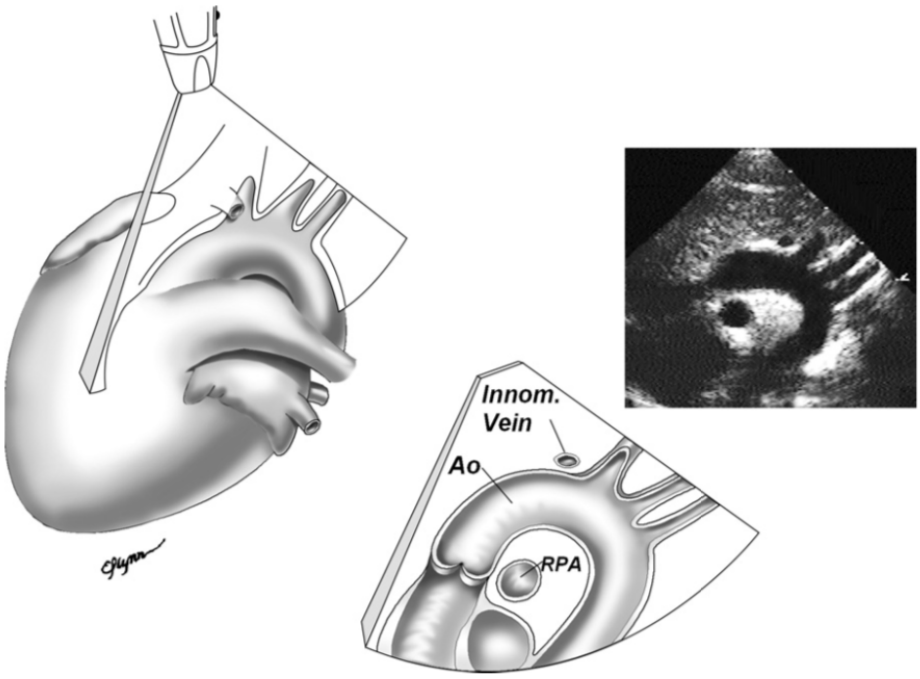
Suprasternal views



Ao Arch 2d

Obtain a view of the aorta from ascending and around the arch, the calibre of the arch, origin of first branches and isthmus should be clearly seen.

Ao arch colour map

Add colour to the above view with colour scale appropriately adjusted to demonstrate alignment of flow throughout the Aorta. If there is evidence of narrowing or turbulence on the colour views velocities should be interrogated with PW / CW

> ***Technical tips.*** *These views can be obtained in a single clip using a colour compare function. This approached is also acceptable / preferred for the lower aorta and ductal views.*

Descending aorta 2d and colour and PW

Views of the distal aorta to the level of the diaphragm should be obtained. It is ideal to visualise the whole aorta in the shape of a "field hockey stick". Flow in the distal aorta should be clearly visualised and a PW gate placed to interrogate the flow velocity at the most distal point possible. this serves not only to exclude a distal coarctation in the part of the aorta that is acoustically shielded by the trachea and oesophagus, but also can be used to inspect for ductal steal.

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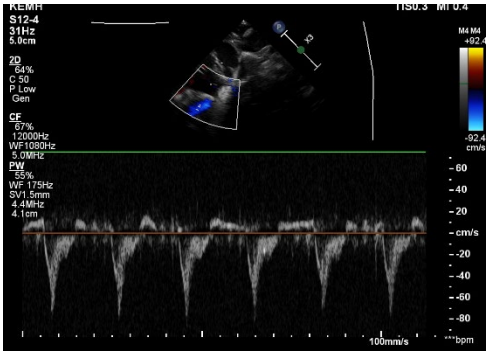


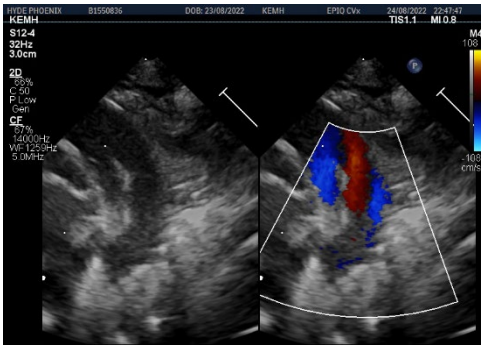
SVC diameter

This is a non-standard view that is solely used to measure the diameter of the SVC. It is not relevant unless an accurate SVC VTI has been obtained *(See "Subcostal SVC view")* and is therefore often an "add on" to the scan. The view is obtained from a left parasternal window with the notch at 12 O'clock. By angling into the right chest the ascending aorta should be an obvious structure, angling further to the right will bring the SVC into vision which courses to the right and just behind the aorta. Measure either directly from the 2d clip or from an M-mode image.

Technical tips. *If doing this last, don't forget to reinvert the image.*

Ductal views, 2d and colour

Either individual or simultaneous 2D and colour views (colour compare) through the MPA, DA and aorta should be obtained. In premature infants the original course of the DA is usually visible even if closed. A colour map should be used to confirm the direction of flow in the DA, if flow is present this should be interrogated with PW.



Technical tips. *The diameter of the DA is best measured in this view. The best appreciation of the DA is usually obtained from a "colour compare" view and measurements from the 2D grayscale image are usually most accurate. Again, take care not to miss a pure right to left duct in pulmonary hypertension.*

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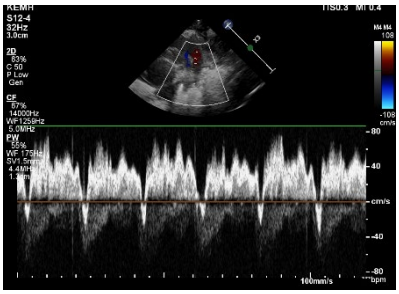
Ductal view PW

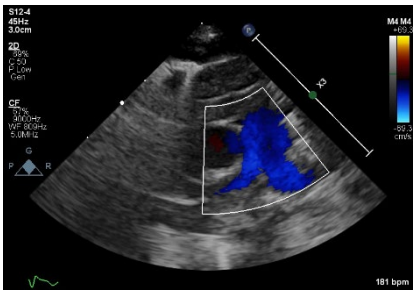
If the DA is patent a PW probe (CW if very high velocity) should be placed in the centre of the vessel taking care to minimise the angle of insonation. The ductal flow direction and velocity should be recorded throughout the cardiac cycle.



High Parasternal Views

Branch Pulmonary arteries

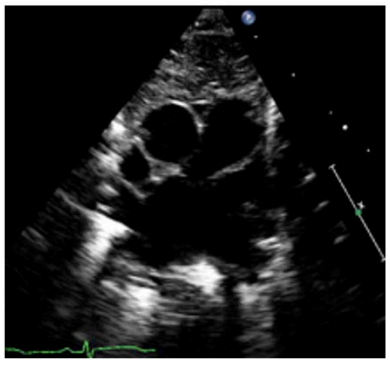
This view is obtained by sliding the probe higher on the chest with the probe horizontally positioned, notch at 3 O'clock. The pulmonary bifurcation and bilateral PA branches are easily visualised. The distal LPA is better profiled in this view than standard parasternal views.

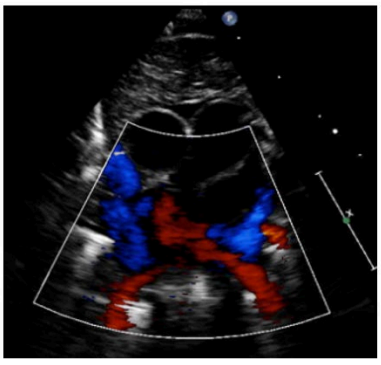


'Crab' view of pulmonary veins

By aiming deeper (towards the vertebrae) the LA will come into view. A colour AOI needs to be set to encompass just beyond the LA and the colour scale reduced (40-60 cm/s), two inferior (red) and two superior (blue) pulmonary veins should be seen.

> ***Technical tips.*** *For this view starting with a colour window is preferable. It is not always possible to get both R and L pulmonary veins in a single view, imaging separately is acceptable.*





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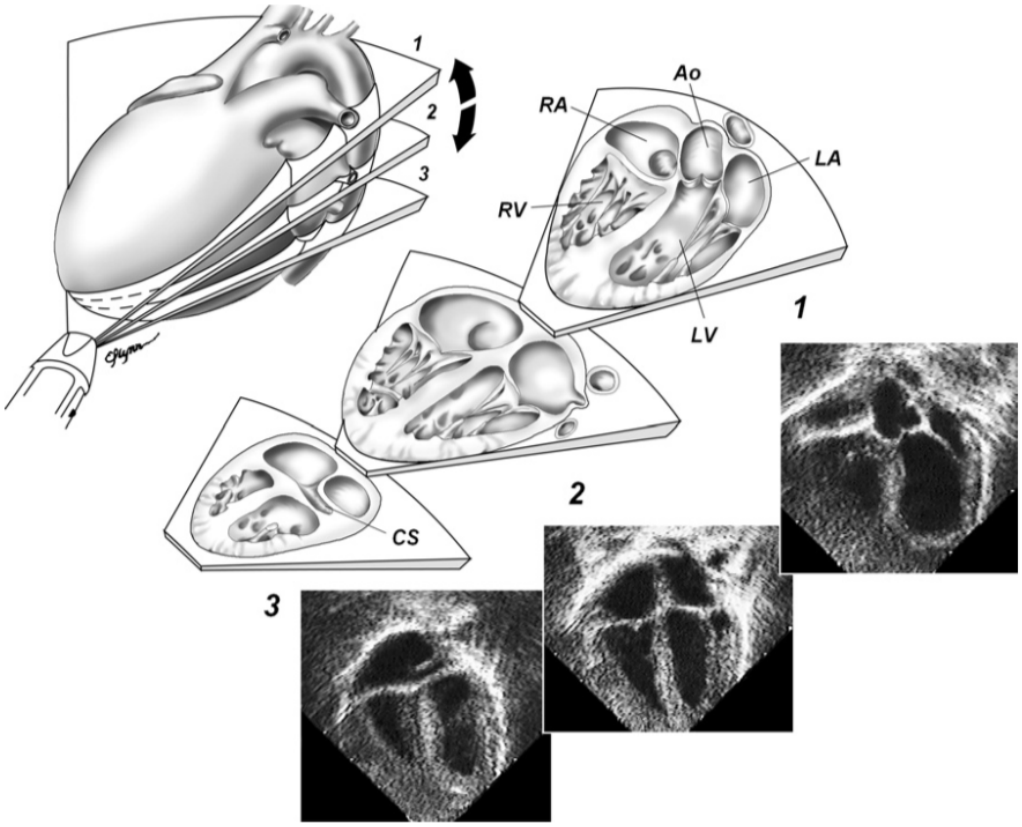
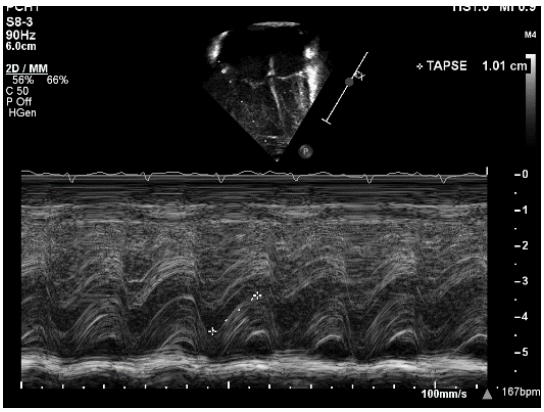
Apical 4 and 5 chamber views



Apical 4 Chamber 2D view

These views should be inverted (anatomically correct). The probe is placed on the apex of the heart and a view of all four chambers obtained. In preterm neonates the heart may be horizontal in the chest and the apex laterally placed, greater anticlockwise probe rotation may be required in the preterm than the 3 o'clock position suggested for term neonates. The septum should be as near vertical as possible and both the MV and TV should be seen to open and close.

With an M-Mode cursor placed through the lateral annulus of the tricuspid valve, TAPSE (Tricuspid Annular Plane Systolic Excursion) can be measured



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Apical 4 chamber colour

The colour box should be placed over both AV valves documenting diastolic filling and looking for any signs of regurgitation. If regurgitation is present the velocity waveform should be interrogated with CW. Colour should also be placed over the septum to exclude a VSD.

Apical 5 chamber view

From the 4 chamber view the beam is directed anteriorly (aiming more towards the right shoulder) to bring the left ventricular outflow tract into view. Further clockwise rotation of the probe may be required.

Apical 5 chamber colour

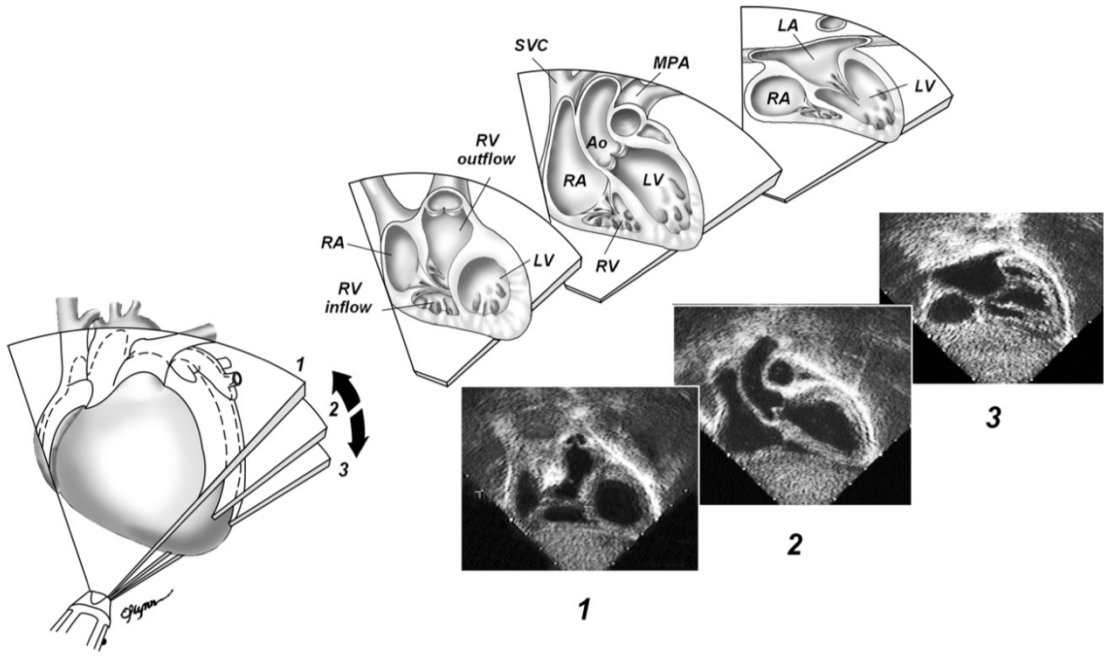
A colour A0I should be placed across the aortic valve to clearly demonstrate lamina flow through the LVOT. Any regurgitation or aliasing should be further interrogated with CW Doppler.

> ***Technical tips.*** *If this view is used* to measure LVOT VTI care must be taken to ensure a good angle of insonation in both the XY and Z planes. This view is not always easy in a neonate and a better angle of insonation may be obtained from a subcostal view.

Apical PA view

A view of the RVOT may be obtained by directing the beam even more anteriorly. The PV should be seen crossing anterior to the aorta and may be visualised up to the bifurcation. in many neonates the lung fields will obscure this view.

Subcostal views



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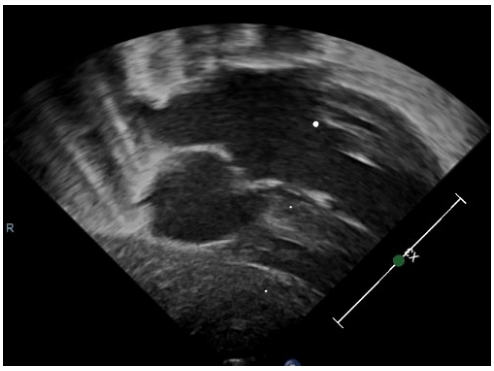
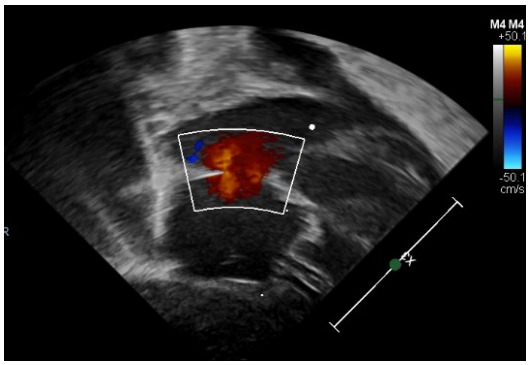
Atrial septum 2d and colour

A subcostal long axis view can be obtained by positioning the probe to the right of the xiphisternum with the notch at 3-4 O'clock. By angling fairly deep (beam more towards back – 3 above) the atrial septum can be visualised. The flap valve of the foramen ovale will be evident. Flow across the FO can be interrogated with colour mapping, this will be relatively low velocity so scale the Doppler accordingly.

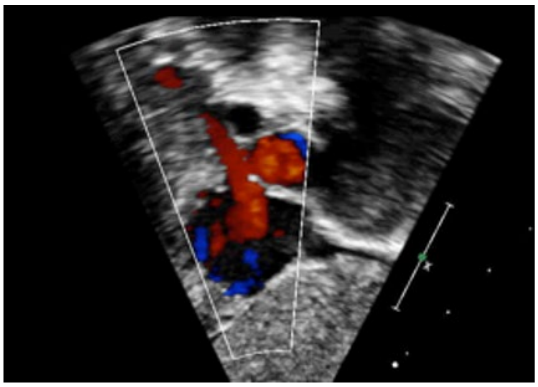


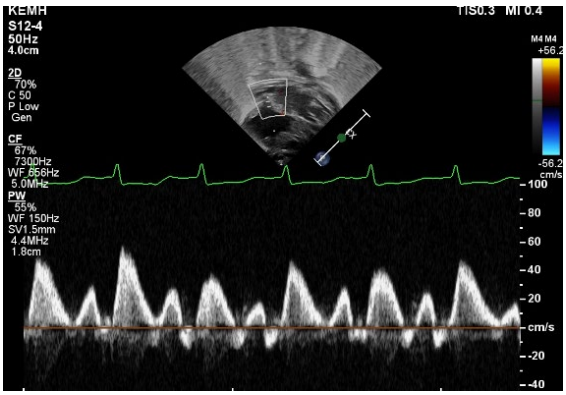


Subcostal SVC view

By bringing the beam a little more anterior the SVC and Ao should come in view (2 above). In practice a little clockwise rotation will result in a better visualisation of the length of the SVC (nearer a bicaval view). Colour compare images of the SVC flow can be recorded.

Technical tips. *If measuring SVC VTI care must be taken to maximise the length of the SVC to minimise the angle of insonation in all planes. A PW gate should be placed in the centre of the vessel above the funnel point into the RA. It is helpful to record the colour image to verify this.*





In a spontaneously breathing baby a continuous trace may be difficult as the heart moves through the respiratory cycle.

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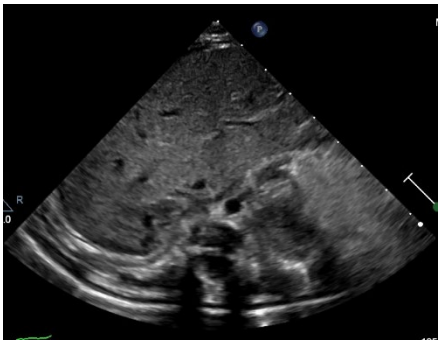
Transverse and Longitudinal abdominal views

Abdominal situs and abdominal great vessels

These views are classically not inverted and use the general radiology convention with notch up or to the right.

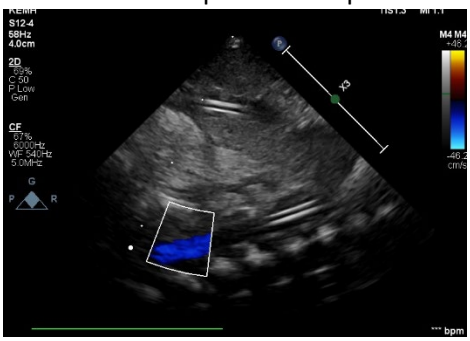


Abdominal situs showing descending aorta and IVC.

While an anatomical cardiology scan will generally start with these views in a neonatal exam they are often left till last. In the right subcostal position rotate the notch to 12 O'clock. The IVC should be traced behind the liver and into the RA. Hepatic veins can be seen joining the IVC. 2d and colour images should be recorded.

Technical tips. *If a UVC is present it can generally be visualised from this window.*

To view the abdominal aorta, maintain the notch at 12 O'clock and sweep a little to the babies left. The aorta will be deep in the left paravertebral gutter. 2d and colour images should be recorded.



Technical tips. *Even though we are measuring an arterial signal the angle of insonation in this view is near 90° and a low scale should be used on the Doppler (<50 cm/s). The Doppler signal may be further improved by angling the probe in its long axis. Note both a UAC and UVC in this image.*

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