Echocardiography and the neonatologist

Lindsey Hunter
Neil Patel

Abstract
Echocardiographic assessment can be broadly divided into functional and structural assessment. Functional echocardiography in the hands of an appropriately trained neonatologist is an accessible and useful modality in the neonatal intensive care unit. This tool allows the neonatologist to assess various parameters, e.g. ventricular outputs and SVC flow, ventricular function, pulmonary pressures and ductus arteriosus and implement immediate management as result. It is essential that there is support from the paediatric cardiologist to prevent misdiagnosis of congenital heart disease and implement further management.

Keywords ductus arteriosus; echocardiography; functional assessment; neonatal intensive care; structural assessment; SVC flows; ventricular function

Part 1: overview of practice

Over the past decade echocardiography has increasingly become both a useful and accessible modality within neonatal units. Echocardiography (echo) is a powerful tool in the hands of an appropriately trained operator. Echo assessment can be broadly divided into functional and structural assessments. There is a distinct overlap between the two assessment categories, each will inform the other and neither should be considered in isolation.

Structural assessment of congenital heart disease is imperative to delineate basic and complex cardiac anatomy including identifying significant anomalies.

Functional assessment is an evaluation of myocardial function and haemodynamics. Although introduced primarily a research tool, functional echo is increasingly employed at the bedside by neonatologists. Serial measurements are used to answer specific and immediate clinical questions in the context of the rapidly changing haemodynamics of a sick neonate.

Functional echo should be performed as an adjunct or in addition to existing clinical parameters; e.g. lactate, CRT, heart rate, blood pressure which are of limited value and are open to observer variability. Functional echocardiography provides a direct measure of myocardial function, pulmonary and systemic blood flows and also intra/extra cardiac shunting.

Who should undertake echocardiograms within the neonatal intensive care? Practicalities, location and politics can often delay a cardiology assessment within neonatal units. Traditionally the diagnosis and management of significant and complex congenital heart disease has been the realm of the appropriately skilled and experienced paediatric cardiologist. However, if functional echocardiograms are performed by the attending neonatal team frequent assessment and therapeutic adjustment can be made without the immediate input of paediatric cardiologist.

The neonatology team must be aware that functional assessment does not exclude structural heart defects. This also highlights a potential medico-legal debate surrounding neonatologists undertaking echocardiograms routinely; the main concern being the potential to misinterpret or even misdiagnose life threatening congenital heart disease. Neonatologists must be are aware of their limitations when structurally assessing the neonatal heart; in particular there are diagnoses which even an experienced cardiologist may find difficult to make or have the potential to miss including coarctation of the aorta, total anomalous pulmonary venous drainage (TAPVD), anomalous left coronary artery (ALCAPA), congenitally corrected transposition of the great arteries and atrial isomerisms.

To ensure neonatologists are adequately trained and that echocardiography within the neonatal intensive care is safe, open and easily accessible lines of communication between the paediatric cardiologists and the neonatologists is desirable. We recommend a model of support for neonatologists by paediatric cardiologists at a ward level, continuing medical education (CME), echocardiography courses, training materials and ongoing positive feedback. There should be opportunities for the neonatal trainees to work alongside the cardiologists in the form of an official placement. In the UK and worldwide, including at our centre, formally-accredited echocardiography courses are run which are appropriate for neonatologists and allied professionals.

In our hospital there is a close working relationship between the paediatric cardiologists and neonatologists with a specialist interest in cardiology. This allows for prompt and timely assessment of newborns with abnormal clinical examination findings or clinical parameters. Both teams meet weekly to discuss the ongoing care of those neonates with significant heart disease in the NICU.

Part 2

The second part of this article focuses on the specific functional echocardiographic measures which are used frequently in the neonatal intensive care unit. It is important to stress that these should always be accompanied by a complete assessment of cardiac structure, as discussed above. Whilst we hope to provide some practical insights into these assessments, it is beyond the scope of this article to teach these techniques.

Assessment of the ductus arteriosus (DA)

Assessment of the DA is most frequently performed in pre-term infants, in whom consideration may be given to closure by surgical or medical therapies, but is also important in

Lindsey Hunter *MBChB MRCPCH is a Paediatric Cardiology Specialist Trainee in the Cardiology Department Royal Hospital for Sick Children, Glasgow G3 8SJ, UK. Conflicts of interest: none.*

Neil Patel *BA MBChB MRCPCH MD is a Consultant Neonatologist in Neonatal Intensive Care at the Royal Hospital for Sick Children, Glasgow G3 8SJ, UK. Conflicts of interest: none.*

duct-dependent congenital cardiac disease and for assessment of pulmonary artery pressures.

The DA is typically directly visualized from a high left parasternal view. From this position the entire length of the DA can be demonstrated between proximal descending aorta and pulmonary artery, and a Doppler of flow velocities and directions may be performed (Figure 1).

The diameter of the DA may be measured at its insertion into the pulmonary artery from 2-dimensional and colour Doppler images. Any constriction of the PDA usually occurs at this point. Ductal diameters, and the presence of constriction, may assist prediction of spontaneous duct closure.

There is increasing interest in defining a haemodynamically significant ductus arteriosus (HSDA). This depends on combined echocardiographic and clinical assessment, and may be assisted by a scoring system such as that proposed by McNamara et al. (Ref). Echocardiographic findings in HSDA are of moderate to large sized ductus with unrestricted left-to-right flow of reasonably high velocity. The echo may also demonstrate reversed diastolic flow in the proximal descending aorta which may accompany evidence of impaired abdominal end organ perfusion.

The shunt size through a DA may also be assessed indirectly by measurement of the left atrium:aortic diameter ratio (LA:Ao). A left-to-right ductal shunt leads to increased pulmonary venous return, leading to enlargement of the LA and an increase in the ratio. Both LA and Ao diameters are obtained from a parasternal, long-axis m-mode image, the aortic valve diameter is measured at end diastole and the maximal LA diameter at end systole. A ratio of greater >1.5:1 is associated with a HSDA.

Management of the HSDA remains controversial and variable. Early targeted treatment using NSAIDs, ibuprofen or indomethacin, is advocated by some authors to achieve greater rates of DA closure and minimize the pathological consequence of an HSDA. Serial echocardiography allows more selective, targeted and shorter courses of NSAID to be given, thereby minimizing the risks of side effects.

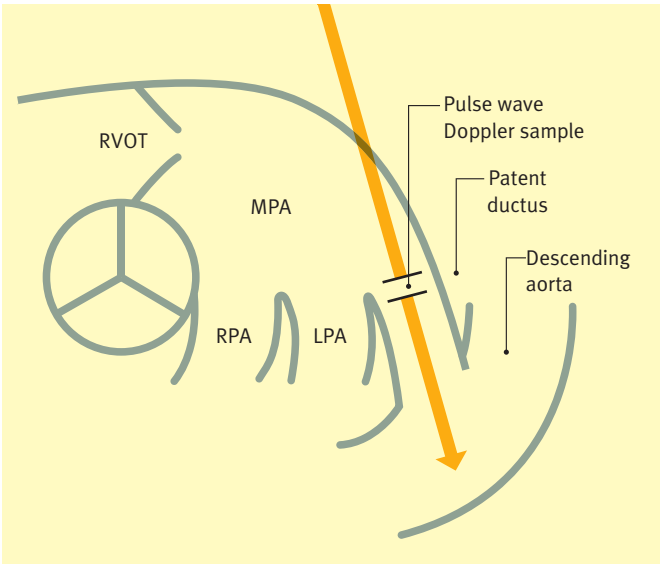

Figure 1 Schematic diagram of DA demonstrating position for Doppler of DA flow.

Calculation of ventricular outputs and superior vena cava (SVC) flows

Measurement of systemic blood flow, combined with blood pressure allows more informed therapeutic decisions to be made in the haemodynamically compromised infant. Echocardiography allows non-invasive measurement of flows in infants where invasive flow monitoring is too risky or technically challenging.

Calculation of flows requires measurement of a valve diameter, or vessel, to calculate its cross sectional area (CSA). A pulse wave Doppler flow of velocity against time is then obtained across the valve, or within the vessel, and the area under this traced for one cardiac cycle to generate the velocity time integer (VTI). The flow (in volume/time) is equal to the product of CSA, VTI and heart rate and is often divided by weight for expression as ml/kg/min.

$$\text{Cardiac output} = \text{Velocity time integer} \times \text{valve cross sectional area} \times \text{heart rate}$$

Right and left ventricular outputs may be measured this way and have been shown to change in RDS, PDA and high output states. In the absence of any shunts right (RVO) and left ventricular outputs (LVO) are equal to each other and systemic blood flow (SBF), and are normally between 220 and 250 ml/kg/min. However, atrial and ductal shunts are common in pre-term infants (refs) and will lead to differences between RVO and LVO, such that ventricular outputs cannot be considered equal to SBF.

It has therefore been suggested that measurement of SVC flow, i.e. blood flow returning to the heart, may provide a better proportional measure of SBF, independent of shunts. A subcostal Doppler of SVC flow entering the RA is obtained and combined with SVC diameter measurements from long-axis views to calculate SVC flows, which are normally around 80 ml/kg/min.

$$\text{SVC Flow} = \text{Velocity time integer} \times \text{SVC cross sectional area} \times \text{heart rate}$$

SVC flows appear to be low in a proportion of pre-term infants (newborn low output state) who may be at risk of hypotension, IVH and neurodevelopmental abnormality (HUNT).

Although not in widespread clinical use, appropriately trained and equipped neonatal units may routinely measure ventricular outputs and SVC flows.

It should be appreciated that the error in any flow measurement may be as high as 25%, due to the numerous measurements involved.

Ventricular function

Ventricular function assessment is complicated by the complex nature of the cardiac cycle and 3-dimensional geometry of the ventricles.

Rapid clinical assessment of ventricular function is often based on subjective opinion from 2-dimensional images obtained in the long and short parasternal axes and apical 4-chamber views. This technique has the significant limitations of being subjective, observer dependent and non-quantitative.

Quantitative volumetric measures of LV function include ejection fraction and fractional shortening, calculated from