Echocardiography and the neonatologist

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Abstract

Neonatal echocardiographic assessment is a component of neonatal point of care ultrasound and can be broadly divided into structural and functional cardiac 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 haemodynamic parameters including ventricular outputs and superior vena cava (SVC) flow, ventricular function, pulmonary arterial pressures, arterial ducts 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 arterial duct; 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 a useful and accessible modality within the neonatal intensive care unit (NICU). It is an effective tool in the hands of an appropriately trained operator, particularly when used as an adjunct to clinical assessment. Echocardiography is a fundamental component of 'neonatal point of care ultrasound' also known as 'targeted neonatal echocardiography' and can be broadly divided into functional cardiac assessment and structural cardiac assessment. There is a distinct overlap between the two assessment categories, as each informs and complements the other.

Structural assessment is essential to delineate the cardiac anatomy, in particular to identify or exclude congenital heart disease (CHD). In contrast functional echocardiography (fEcho) assessment is used to evaluate myocardial function and the haemodynamic stability of sick term or preterm neonates. Although introduced primarily as a research tool, fEcho is increasingly employed at the bedside by neonatologists. International guidelines have been published by the American Society of Echocardiography (ASE) in conjunction with the European Association of Echocardiography (EAE) and the Association for European Paediatric and Congenital Cardiology (AEPC), discussing the importance of targeted neonatal echocardiography.

fEcho should be performed as an adjunct to existing clinical parameters, for example: lactate; capillary refill time (CRT); heart rate and blood pressure, which are open to observer variability. fEcho is employed to make serial measurements and to answer specific clinical questions. In particular, it provides a direct measure of myocardial function, pulmonary and systemic blood flow and intra/extra cardiac shunting.

Traditionally the diagnosis and management of significant and complex congenital heart disease has been the realm of the paediatric cardiologist and this continues to be international practice. Neonatologists must be are aware of their limitations when assessing the structure of the neonatal heart as even in the hands of experience echocardiographers certain diagnoses can be challenging and devastating if missed, for example: coarctation of the aorta and total anomalous pulmonary venous drainage (TAPVD). For this reason the initial neonatal echocardiogram must involve a comprehensive assessment of the cardiac anatomy, in addition to a full functional assessment. As per international guidelines this initial echocardiogram should be reviewed by a paediatric cardiologist within a mutually agreed time frame. A clear distinction must be made between an echocardiogram undertaken in infants with CHD, and fEcho to assess haemodynamics and myocardial function in a structurally normal heart. Once structural CHD has been excluded, subsequent echocardiograms can focus on the functional cardiac status. fEcho performed by the attending neonatologist allows for frequent assessment and therapeutic adjustment, without the immediate input of a paediatric cardiologist.

To ensure neonatologists are adequately trained and supported, open and easily accessible lines of communication between the paediatric cardiologist and the neonatologist is desirable. We recommend a model of support at ward level, by continuing medical education (CME), echocardiography courses, training materials and ongoing positive feedback. Official accreditation for neonatologists undertaking targeted neonatal echocardiography is not consistent internationally. In the UK, Paediatricians with Expertise in Cardiology Specialist Interest Group (PECSIG) has been recognized by the Royal College of Paediatric and Child Health (RCPCH) since 2008, which aims to improve the care children with cardiac conditions receive, by supporting and enhancing the training of paediatricians with expertise in cardiology.

Within Europe, the European Association for Cardiovascular Imaging (EACVI) in conjunction with the Association for European Paediatric and Congenital Cardiology (AEPC) provide accreditation in congenital heart echocardiography, but this is comprehensive and not entirely suitable for neonatologists undertaking targeted neonatal echocardiography. However, in Australasia an accreditation process specifically for neonatologists has been available since 2008: 'The Neonatal Certificate in Clinician Performed Ultrasound' (CCPU in neonatal ultrasound) which was developed by the Australasian Society for Ultrasound in Medicine.

Part 2

The second part of this article focuses on some of the specific functional echocardiographic measurements which are

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frequently utilized in the NICU. As discussed in Part 1, initial echocardiographic assessment should include a comprehensive assessment of the cardiac anatomy. Whilst we hope to provide some practical insights into some of these functional assessments, it is beyond the scope of this article to discuss all available techniques or to teach these techniques.

Assessment of the patent arterial duct (PDA)

Assessment of the arterial duct is most frequently performed in preterm infants, in whom consideration may be given to closure by surgical intervention or medical therapy. Ductal assessment is important in the management of duct-dependent CHD and also aids in the assessment of pulmonary artery pressures within a structurally normal heart.

The arterial duct is visualized from either a high left parasternal or suprasternal view. From this position the entire length of the arterial duct can be demonstrated extending from the proximal descending aorta to the main pulmonary artery (MPA). These views allow for assessment of the ductal diameter, shunt direction and flow velocities by pulse wave (PW) Doppler and colour Doppler assessment. (Figure 1) The diameter of the arterial duct can be measured at its insertion into the MPA by 2-dimensional imaging and primary constriction usually occurs at the pulmonary artery insertion point. The diameter of the duct and evidence of constriction may indicate a potential for spontaneous ductal closure.

There is increasing interest in defining a haemodynamically significant ductus arteriosus (HSDA). Clinically there may be evidence of systemic hypoperfusion or increased pulmonary blood flow, which can impact on longer term morbidity. Deciding whether an arterial duct is haemodynamically significant depends on combined echocardiographic and clinical assessments, and may be assisted by a scoring system, such as that proposed by McNamara et al. Echocardiographic findings in HSDA include a moderate to large sized duct with unrestricted left to right flow, with a high Doppler velocity. Colour flow and PW Doppler may demonstrate diastolic flow reversal in the proximal descending aorta, indicating diastolic left to right shunting at the arterial duct. Clinically this may be accompanied by evidence of impaired abdominal end organ perfusion.

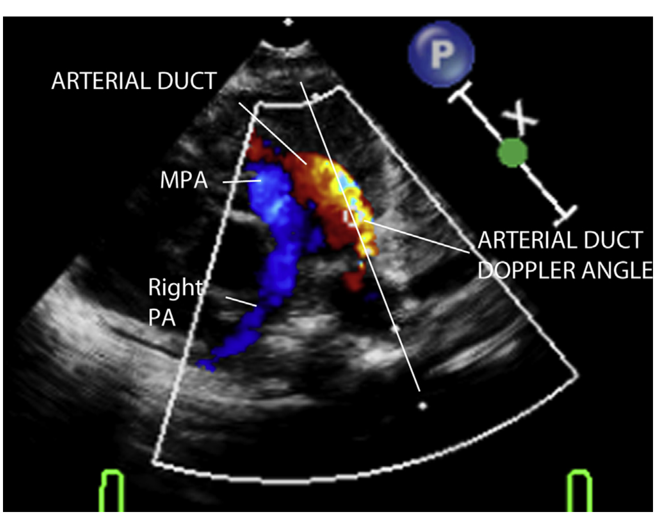

Figure 1 Echocardiographic image of the arterial duct demonstrating position for Doppler of arterial ductal flow.

The shunt flow through an arterial duct may also be indirectly quantified by measuring 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, with a subsequent increase in the LA: Ao ratio. Both the LA and Ao diameters are obtained from an M Mode measurement in the parasternal long axis view. The aortic valve diameter is measured in end diastole and the maximal LA diameter in end systole. A ratio greater than 1.5:1 is associated with an HSDA.

Management of the HSDA remains controversial and variable within NICUs. Early targeted treatment using NSAIDs for example ibuprofen or indomethacin, is advocated by some authors to achieve greater rates of arterial duct 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 side effects.

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 deemed too risky or may be technically challenging.

Calculation of flow 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 mls/kg/minutes.

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

Right and left ventricular outputs may be measured this way and have been shown to change in association with respiratory distress syndrome (RDS), arterial ducts and high cardiac output states. In the absence of any shunts right ventricular output (RVO) and left ventricular output (LVO) are equal to each other and therefore systemic blood flow (SBF), and are normally between 220 and 250 mls/kg/minutes. However, atrial and ductal shunts are common in preterm infants 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 right atrium (RA) is obtained and combined with SVC diameter measurements from long axis views to calculate SVC flows, which are normally around 80 mLs/kg/minutes.

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

