

Hemodynamic management of the preterm infant with acute respiratory failure: role of the functional echocardiography

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Summary. The functional echocardiography is a useful tool to evaluate the hemodynamic status of preterm infants, often needing a respiratory support during the first critical days of life. In NICU it can be helpful either for the clinical monitoring or the therapeutic management and the use of this technique can potentially improve short-term outcome of preterm infants. (www.actabiomedica.it)

Key words: functional echocardiography, hemodynamic status, preterm infants

Introduction

The term “functional echocardiography” describes the use of echocardiography as an adjunct in the clinical assessment of the hemodynamic status in newborn infants. Usually pediatric cardiologists perform echocardiographic studies in the Neonatal Intensive Care Units (NICU) to diagnose or to monitor congenital heart diseases (CHD) and to screen for patent ductus arteriosus (PDA). However, neonatologists frequently have to deal with the management of hemodynamically instable preterm neonates and only a small proportion of these neonates may present an undiagnosed CHD in this setting (1-3).

The assessment of ventilated preterm infants with cardiovascular compromise is one of the main challenges for neonatologists and, at present, continuous non-invasive real-time monitoring of cardiac function and hemodynamic status is not routinely available (4).

The cardiovascular compromise in these patients is the result of prenatal and postnatal factors that adversely affect organ perfusion during the period of

postnatal transition, especially in the presence of immature myocardium (5, 6).

Clinical signs of poor perfusion are useful but not sufficient to evaluate the cardiovascular status and there is a poor relationship between blood pressure (BP) and systemic blood flow (SBF), particularly in the context of highly variable systemic vascular resistances (SVRs) (7-9).

The functional echocardiography satisfies the need to obtain real-time information by a non-invasive and easily reproducible method that can provide data useful for the clinical decision-making. This technique, performed by adequately trained intensivists, can change the clinical management and potentially improves short-term outcome (3, 10, 11). At present no data exist on long-term outcome.

In order to get reliable echocardiographic parameters it is necessary to repeat measurements using more than one method, to minimize inter- and intra-observer variability, to achieve good quality of images also in the presence of hyperinflated lungs in ventilated preterm infants.

Hemodynamic compromise

Prematurity increases the need for invasive and non-invasive respiratory support and infants with severe respiratory distress syndrome (RDS) may have lower BP than infants with less severe or without RDS (12, 13). Different factors, often acting together, influence the relationship between BP and SBF:

- 1) The increased airway pressure depending on the type of invasive ventilation (conventional or high frequency ventilation) and the use of positive-pressure ventilation influence SBF. Many authors report a negative correlation between the mean airway pressure in mechanical ventilated preterm infants and the BP. High ventilation pressures can reduce the preload by reducing systemic and/or pulmonary venous return, while direct compression of cardiac chambers increases the afterload and reduces the stroke volume. So mechanical ventilation alters intrathoracic pressure and thereby affects the cardiovascular system, mainly the right ventricle (RV); however, considering an in-series circulation, a reduction of the RV output also reduces that of the left ventricle (LV) (14, 15, 16). In addition, a too high positive end-expiratory pressure (PEEP) and, presumably, the resultant hyperinflation of the lungs may induce the release of plasmatic factors having negative inotropic action (17). Current data show a decreased necessity of mechanical ventilation by using early nasal continuous positive airway pressure (nCPAP) with early surfactant administration. The INSURE method (Intubation - Surfactant - Extubation) followed by positioning nCPAP potentially can reduce the incidence of hypotension and decreased perfusion in very low birth weight (VLBW) infants (18).
- 2) Blood losses may further reduce the preload; a delayed cord clamping (DCC) reduces the risk of hypovolemia (19).
- 3) There is a close relationship between SVRs and cardiac output; different factors affect SVRs such as carbon dioxide level, unbalance of vasoactive substances, inadequate immature sym-

pathoadrenal system and sepsis. Furthermore, during the first hours of life (very vulnerable status) the enhanced SVRs can significantly decrease SBF with consequent poor neonatal outcome (20, 21).

- 4) PDA, which exposes LV to the combined pulmonary and systemic vascular resistances, plays an important role in determining hemodynamic instability when it is significant (22, 23).
- 5) The role of myocardial dysfunction as a primary cause of hypotension in severely asphyxiated preterm infants is well-documented (24). Transient dysfunction is usually the result of an unsatisfactory response of immature myocardium to the suddenly increased left afterload and can play a role in the development of a low flow in the superior vena cava (SVC) (25).

Functional echocardiography

The functional echocardiography allows the evaluation of different useful parameters: blood flow measurements; measurements of myocardial performance, ductal and atrial shunting, pulmonary artery pressure (PAP). The complex relationship among these parameters in the unique condition of the transitional circulation implies a complete evaluation of all these measurements for the correct assessment of the preterm infants' hemodynamic status.

- Blood flow measurements
Three main measures are necessary to estimate stroke volume: mean flow velocity, cross-sectional vessel area and heart rate. To minimize measurement errors, the flow must be laminar and sampled at an angle $< 20^\circ$ while the vessel diameter must be achieved when the ultrasound beam hits the vessel at 90° . It is important to consider that the LV output can be used to estimate SBF only in the absence of ductal shunt, otherwise it becomes an index of pulmonary blood flow as the sum of the SBF and the left to right shunt across the duct. In this situation, the RV output is a better measure of the SBF. There is a good correlation between RV and LV out-

put in the absence of atrial and ductal shunts, but a large left to right shunt overestimates RV output (4). The SVC flow is independent of shunts and represents the portion of SBF for the brain and the upper body. Its measurements is technically difficult and in newborns breathing spontaneously requires to average from 10 cardiac cycles (4). A low SVC flow relates to a poor neurological outcome (26).

- Measurements of myocardial performance

The simplest measure of the LV systolic function is the fractional shortening (FS), commonly derived from a M-mode study. Unfortunately, during transitional circulation, the individual fall time of pulmonary vascular resistances (PVRs) and the close interdependence of the two ventricles affect the septal and LV anterior wall motion, making the FS a not very reliable measure. Other methods to evaluate myocardial performance have been suggested (4, 27). An important limit of the estimation of the global systolic function is the impossibility to differentiate how each of the three major components (preload, afterload and intrinsic contractility) affects the changes. The estimation of the velocity of circumferential fiber shortening (VCF) and the relationship between VCF and wall stress (WS) (28) are helpful, but not so easy to be performed in clinical practice. In future, the functional study of the immature heart with the tissue Doppler technique could provide many advantages.

- PDA

The echocardiographic assessment of PDA includes different parameters: ductal diameter, transductal flow pattern, mean left pulmonary artery (LPA) velocity, signs of left heart volume and pressure overload (LA/Ao ratio, mitral regurgitation jet, E/A ratio, isovolumic relaxation time IVRT), arterial diastolic reverse flow in the normal end-organ vessels (cerebral, mesenteric, and renal arteries). The risk of hemodynamically significant PDA increases with low gestational age and, although it has been linked to important neonatal morbidities (early pulmonary hemorrhage, chronic lung disease and neonatal necrotizing enterocolitis), there is little evidence

that its treatment improves either short-term or long-term outcomes (22, 23, 29). However, echocardiographic criteria such as ductal internal diameter greater than 1.5 mm, LA/Ao greater than 1.5, absent or retrograde diastolic flow in postductal descending aorta, increased mean LPA velocity, in association with demonstrated adverse clinical effects, address to PDA closure (30, 31).

- Atrial shunting

In preterm babies left-to-right atrial shunt can be both significant and quite persistent; atrial shunting is determined predominantly by RV filling or diastolic pressure. It can contribute to increase pulmonary blood flow and overestimates the SBF in the presence of PDA. A bidirectional shunt alone is not a marker of pulmonary hypertension; an exclusive right-to-left atrial shunting is rare and should be investigate for CHD (4).

- PAP

PAP echocardiographic estimation is obtained by measuring tricuspid regurgitation jet or ductal shunt and the direction of atrial shunt (4). When pulmonary hypertension (usually a problem of term or near term newborn) affects preterm neonates, excluding a CHD or a secondary cause such as pulmonary embolism is mandatory.

Conclusions

Currently there is agreement to perform an echocardiography during the first 12 hours of life in extremely low-gestational-age (ELGA) infants and in the preterm neonates born after 27 weeks of GA with respiratory compromise, to monitor the vulnerable transition period. This evaluation must include:

a) the measurement of SBF with a simple method: if atrial shunt is not very large, maximum velocity in the main pulmonary artery (MPA) greater than 0.45 m/sec most likely excludes low SBF; on the contrary, when maximum velocity in MPA is lower than <0.45 m/sec, it is necessary to estimate the RV output and to evaluate the SVC flow (32);

b) the ductus arteriosus assessment: early constriction or patency, considering that significant left to right shunt is often clinically silent during the first hours or days of life.

Further echocardiographic assessments are necessary when there is the suspicion of a circulatory compromise or, longitudinally, to follow the effectiveness of some therapeutic decisions. A full assessment of ductal patency, the measurement of LV and RV output and the indirect (visual) and/or direct (FS, VCF, tissue doppler) measurement of the myocardial function can better address clinical decision.

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