

## Review Article

# Training basic echocardiography to pediatric residents: need of the hour

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### ABSTRACT

Most of the cardiac abnormalities which pediatricians come across, require echocardiography for confirming the diagnosis. Due to the introduction of 'point of care ultrasonography' and widespread availability of ultrasonography equipment in clinical care areas, pediatricians are able to diagnose some of these cardiac abnormalities; however, they are unable to make a prompt echocardiographic diagnosis by themselves in most of these cardiac conditions due to lack of echocardiography skills. Pediatric residents and consultants, especially those who are involved in providing care in pediatric emergency, pediatric ICU, and neonatal ICU, should learn the skills of basic echocardiography for making the quicker diagnosis of such conditions and improving patient care. Subcostal view echocardiography can detect many cardiac abnormalities through a single echocardiographic window. There is a need of formulating a need-based basic Echocardiography training program to be incorporated into the Pediatric residency curriculum.

**Keywords:** Pediatric, Echocardiography, Point of care ultrasonography, Subcostal view, Resident training

### INTRODUCTION

Pediatricians often come across children with suspected cardiac problems in clinical practice.<sup>1</sup> This can be an emergency condition like cardiac tamponade due to large pericardial effusion, cardiogenic shock due to severe systolic dysfunction in any child with myocarditis or this could be a relatively stable condition like congestive heart failure due to acute rheumatic fever. In the neonatal age group, this could be any cyanotic cardiac lesion like transposition of great arteries, duct dependent lesions like critical aortic stenosis or pulmonary stenosis, requiring early recognition of these structural lesions for further management. Confirmation of the diagnosis of such conditions requires imaging by echocardiography. The diagnosis might be delayed if the attending pediatrician is not trained in echocardiography. On the other hand, if the on-duty resident is trained in doing echocardiography, the underlying cardiac structural or functional abnormality can be revealed early or it can be ruled out. With the advent of technology in the last 2 decades, there has been

a widespread availability of portable ultrasound machines for clinicians involved in emergency and ICU care. Though the contribution of bedside echocardiography in the diagnosis and management of children with cardiac disease is invaluable and it is considered as a 'stethoscope of future', there is a lack of echocardiography skill among general pediatricians. Training them about the basic echocardiography skills to recognize pediatric cardiac diseases would help in better management of such children.<sup>2</sup>

### DISCUSSION

Point of care ultrasonography (POCUS) was introduced to the emergency physician way back in 1980.<sup>3,4</sup> POCUS refers to complement the history and physical examination with an immediate relevant ultrasonographic examination. This helps in making a quicker diagnosis and improving patient care. Pediatric-specific POCUS guidelines were published in 2015 and jointly endorsed by the American college of emergency physicians, the

American academy of paediatrics (AAP), the society for academic emergency medicine and the world interactive network focused on critical ultrasound.<sup>5</sup> POCUS involves the ultrasonographic examination of the heart, IVC, and lungs mainly. This training module also teaches evaluating airways, gastrointestinal system, renal system, and optic nerves. The POCUS training module contains a very limited portion of training of echocardiography which includes recognition of pericardial effusion, and evaluation of ventricular systolic function and IVC. It does not include training for the recognition of congenital cardiac lesions and valvular heart lesions with which the paediatricians most often come across. Imaging of such lesions for confirmatory diagnosis is dependent mainly on cardiology or paediatric cardiology physicians. A study from a tertiary care institute of India estimates that approximately 23% of emergency admissions constitute Respiratory diseases, whereas 5% are cardiac diseases.<sup>6</sup>

Although a good knowledge and skill of echocardiography are expected from the paediatricians for identifying a variety of cardiac problems in children; one of the simpler modules to diagnose most of the cardiac problems and assessing IVC is subcostal view echocardiography. A study conducted at a tertiary care institution of Eastern India (Patna) on the efficacy of basic echocardiographic training to 20 paediatric residents, estimated that a three-day hands-on training of basic echocardiography with emphasis on subcostal view echocardiography can make them skilled in basic echocardiography to identify various cardiac structures and most of its abnormalities including valvular and shunt lesions. Jacob et al estimated the diagnostic accuracy of echocardiography performed by paediatricians with experience in cardiology. For 82% of children, there was a complete diagnostic agreement between the Paediatrician with experience in cardiology and the pediatric cardiologist. For 10% of children, the main diagnosis was identical with additional findings made by the pediatric cardiologist. In 2% of patients, the pediatric cardiologist made a different diagnosis.<sup>7</sup>

Poon et al advocated the use of functional echocardiography (fECHO) by neonatologists which refers to a bedside, limited assessment of the ductus arteriosus, myocardial performance, and pulmonary or systemic hemodynamics.<sup>8</sup>

There is concern about misdiagnosis by neonatologist performed echocardiography (NPE) and harm to the patient; however, several studies have shown that the use of NPE in the neonatal intensive care unit has resulted in an improvement in patient care without any adverse effects.<sup>9,10</sup> It is always advisable to get the echocardiography reviewed by a cardiologist/pediatric cardiologist in case of doubt and when complex cardiac lesions are suspected.

There is a need for making a local, need-based structured training program, covering common structural and

functional cardiac abnormalities with the incorporation of assessment and certification system, to maintain a reasonable level of standard.

The practice guidelines and recommendations for the use of targeted neonatal echocardiography (TNE), endorsed by the American society of echocardiography, European association of echocardiography, and association for European paediatric cardiology, provide an excellent structured approach to standardized training and maintenance of competency.<sup>12</sup>

### ***Echocardiography equipment***

A portable echocardiographic machine should be stationed or readily available in areas running pediatric emergency, pediatric ICU, and neonatal ICU. It should have functions of 2D echo, color doppler, pulsed wave (PW) doppler, and continuous wave (CW) doppler. The frequency of the probe ranges from 2.5-12 MHz. The lower frequency probe has a higher depth of penetration, hence should be used in older children. The higher frequency probe has a lesser depth of penetration; hence it can be used for neonates and younger children.<sup>13</sup> However, a single probe of frequency 1-5 MHz can be used in children of all age groups.

### ***Basic echocardiographic modes***

The basic modes of echocardiography are-2D echo, M mode, and doppler echo. Doppler echo is of two types; color doppler and doppler for velocity measurement. Doppler for velocity measurements is pulsed wave (PW) doppler and continuous wave (CW) Doppler. 2D echo gives a 2D picture (moving or still) of cardiac structures. Any cardiac structural abnormalities like ASD, VSD, or enlarged chamber size can be visualized. Deformity of any valves and vegetation over valves can be visualized and ventricular ejection fraction can be estimated grossly or it can be measured objectively. M mode (measurement mode or motion mode) echocardiography cuts section of the cardiac structure at any desired level. It is ideal for measurement of the thickness of any cardiac tissue or diameter of cavities like the left ventricle (LV), right ventricle (RV), left atrium (LA), right atrium (RA), or aorta. In color doppler echo, blood going away from the probe is visualized as blue color and that coming towards the probe is visualized as red color (Mnemonic is BART for blue away and red towards). A jet of blood moving under turbulence, like blood flowing through a stenosed valve, regurgitant valve, VSD, or patent ductus is visualized as a mosaic jet consisting of mixed colors: red, blue, and yellow. This mosaic jet is very helpful in identifying these structural lesions. PW doppler measures pressure at any fixed point, but it has a limitation that it cannot measure a higher-pressure gradient. Hence, it is useful for imaging flow across normal valves and flows through low-pressure gradient shunt like atrial septal defect.

### Sub-costal view echocardiography

Sub-costal view echocardiography is one of the basic views of echocardiography; the other three being apical view, para-sternal long-axis view, and parasternal short-axis view. For subcostal view echocardiography the Echo probe (ultrasound probe with a small foot-print) is placed in a sub-xiphoid location with the pointer towards the left side. By making positional changes of the probe, various structures can be visualized and any abnormalities of these structures can be identified (Figure 1). Through this single window, many cardiac anomalies including- atrial septal defect (ASD), ventricular septal defect (VSD), patent ductus arteriosus (PDA), persistent pulmonary hypertension (PPHN), cardiac and infra-cardiac total anomalous pulmonary venous connection (TAPVC), systolic dysfunction in myocarditis, pericardial effusion, cardiac tamponade, tetralogy of Fallot, transposition of great arteries, tricuspid atresia, pulmonary stenosis, and aortic stenosis, can be identified. If the abdomen is not distended it is easier to evaluate the heart through this window. Díaz-Gomez et al have found subcostal view echocardiography a good alternative to apical view echocardiography for measurement of Tricuspid annular plane excursion systolic excursion in patients of congestive heart failure admitted in ICU.<sup>14</sup> Cantinotti et al have evaluated the right ventricular dimension of healthy children using subcostal view echocardiography.<sup>15</sup>



**Figure 1: Probe position for subcostal view echo.**

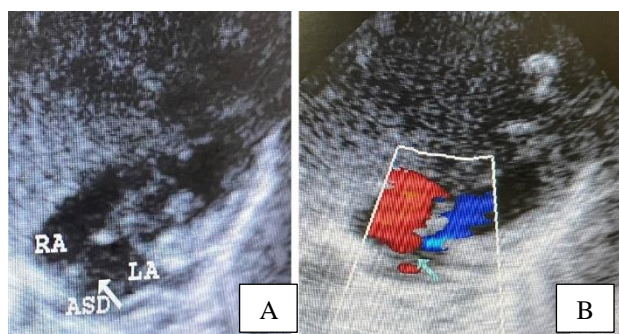
### Using continuous wave (CW) doppler for measuring pressure gradient and pulmonary artery pressure

CW doppler can measure the pressure gradient anywhere across any particular line. CW doppler needs to be aligned across that line. It can measure higher pressure. Hence, it's useful for measuring pulmonary artery pressure and pressure gradient across any stenosed valve or outflow tract. Pulmonary artery pressure is estimated through echo by measuring the pressure of tricuspid regurgitation. The echo machine software automatically calculates the pressure after measuring the velocity of the tricuspid jet or it can be measured by the formula:

Pulmonary artery systolic pressure = (TR jet velocity in m/sec)<sup>2</sup> × 4 mmHg + Right atrial pressure.

The estimated RA pressure is approximately 10 mmHg.

In a study conducted by Maskatia et al a three-day echocardiography training camp conducted for first-year cardiology fellows estimated that it improves self-efficacy in performing an echocardiographic examination and the acquisition and short-term retention of skills and knowledge required to perform pediatric echocardiography.<sup>16</sup> There have been efforts to assist pediatricians in performing echocardiography by telemedicine also.<sup>17,18</sup> For Paediatric residents, the first year of the Junior residency program seems the right time to make them learn skills of basic echocardiography. After this training and practice of this skill subsequently over the rest of the 3-year Junior residency program, they are expected to easily identify the pediatric cardiac problems, at the end of their tenure.

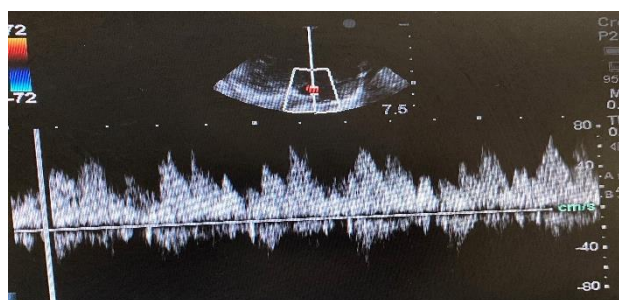


**Figure 2: 2D echo (a) and color doppler (b) atrial septal defect (arrow).**

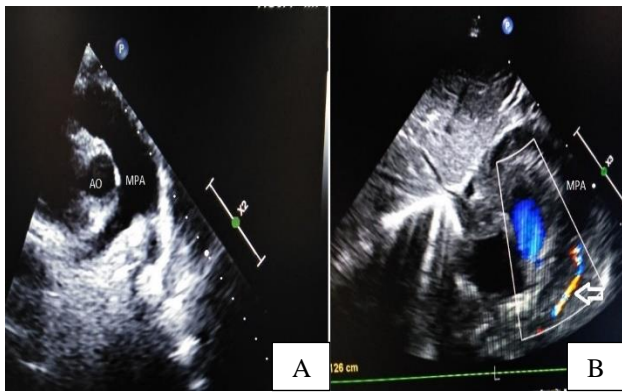
### Calculating LV ejection fraction

Left ventricular ejection fraction (LVEF) in most of the normal adults is around 60%, whereas in healthy children it is 60-70%. A severely depressed left ventricular ejection fraction in acute myocarditis may demonstrate a just flickering myocardium with an ejection fraction of

approximately 15%. Visual estimation of LVEF can be made by carefully observing the myocardial contractility of the left ventricle. Objective measurement of LVEF can be done by the Simpson method.<sup>19</sup> It requires tracing of diastolic and systolic dimensions of the left ventricular cavity by the 2D echo.



**Figure 3: Pulsed wave doppler showing flow across ASD towards left atrium.**

**IVC collapsibility index (IVCCI)**

**Figure 4: Normal pulmonary artery (a) and flow of PDA (b) (MPA-main pulmonary artery, AO-aorta).**

During inspiration, the internal diameter of IVC gets reduced to more than 50% of its size during expiration. Congestive heart failure (CHF) is one of the most common causes of reduced collapsibility. For measuring

the IVC collapsibility index, IVC is measured 2 cm caudal to the junction point of the hepatic vein and IVC. The inspiratory (IVCi) and expiratory (IVCe) diameters of the IVC are then measured.<sup>20</sup>

The IVCCI is calculated as  $IVCCI = [(IVCe - IVCi) / IVCe] \times 100\%$



**Figure 5: Right ventricular collapse (arrow) during diastole in cardiac tamponade.**

**Table 1: Echocardiographic characteristics of common cardiac diseases.**

Cardiac lesion	2D echo	Color doppler	CW/ PW doppler
<b>ASD</b>	There is a defect in the inter-atrial septum (IAS). Any defect seen in 2D echo should be confirmed with color Doppler to look for flow through the defect as sometimes defect in IAS may be seen (echo dropout) in the absence of ASD shown in the Figure 2.	A definite flow across the defect will be seen	As there is a low-pressure gradient shunt, PW doppler is used to further confirm the blood flow through the defect in IAS. The continuous flow across IAS is seen along the direction of blood flow (Figure 3).
<b>VSD</b>	The defect in IVS (interventricular septum) may be seen. The smaller defect may not be visualized. The smaller defect may be revealed through the color doppler.	A mosaic jet of turbulent blood flow across IVS is seen. It can be visualized in the subcostal 4 chamber view, but the parasternal long-axis view may give a better image.	CW doppler further confirms the presence of VSD as intermittent waves of flow during systole. The height of the wave gives a measurement of the pressure gradient across the defect.
<b>PDA</b>	When the horizontally placed echo probe at the subcostal region is rotated anti-clockwise by almost 80 degrees, the pulmonary artery is visualized on the right side of the screen, lying adjacent to the aorta.	PDA is visualized as a mosaic jet inside the pulmonary artery with the direction of the mosaic jet towards the pulmonary valve. The width of the jet provides the size of PDA; usually, the width of the jet is approximately 3mm as shown in the Figure 4.	CW doppler shows a continuous flow towards the pulmonary valve.
<b>TGA</b>	When a large vessel bifurcates soon after coming out from the left ventricle; this vessel is the main pulmonary artery and it is suggestive of d-TGA.	The presence of the main pulmonary artery may be further confirmed by color doppler, showing a great vessel coming out from the left ventricle and bifurcating soon.	-

Continued.



Cardiac lesion	2D echo	Color doppler	CW/ PW doppler
<b>Tetralogy of fallot</b>	A large subaortic VSD is seen with Aortic override. Hypoplastic and narrow pulmonary artery is visualized by rotating the probe to around 80 degrees anticlockwise. There is infundibular pulmonary stenosis (proximal to pulmonary valve).	-	The right ventricular outflow tract pressure gradient is measured by keeping the CW doppler line along the infundibular pulmonary stenosis. There will be high-pressure gradient; usually of 60-70 mmHg.
<b>Tricuspid atresia</b>	The tricuspid valve opening is not visualized. RV is small, associated with large VSD.	-	-
<b>Pericardial effusion/ cardiac tamponade</b>	Pericardial effusion is easily recognized as an echo-free (>3 mm) space around the cardiac border. Cardiac tamponade is usually associated with large pericardial effusion (>20 mm) and is recognized by RV collapse during diastole (Figure 5).	-	-
<b>Myocarditis</b>	Patients presenting in the emergency with CHF due to myocarditis, usually have severe systolic dysfunction which is easily recognized by visual estimation as markedly reduced systolic function ventricles. Objective estimation of LV ejection fraction can be done through Simpson's method.	Acute myocarditis with severe systolic dysfunction is usually associated with mitral regurgitation seen on color doppler.	-
<b>Valvular stenosis and regurgitation</b>	Stenotic lesions (congenital or rheumatic) may appear thickened with restricted movement. Improper coaptation of the valvular leaflet may be seen with regurgitant valves.	A mosaic jet of turbulent flow may be seen in stenotic or regurgitant valves.	CW doppler further confirms the presence or absence of stenosis or regurgitation by pressure wave tracings. It also measures the severity of valvular stenosis. Pulmonary artery pressure can be estimated by measuring the pressure of tricuspid regurgitation.

***Tips for identifying common and critical cardiac lesions/functional abnormalities in pediatric age group through subcostal view echocardiography***

Before doing echocardiography, one should try to quickly obtain the following important information-a brief history, upper and lower limb pulses, SpO<sub>2</sub>, cardiac auscultation, X-ray, and ECG findings. At the beginning of echocardiography, a gross assessment of chamber size and systolic function should be done by a 2D echo. If chamber size is abnormal, then the possible underlying etiologies should be thought of and looked for by further imaging; like a small LA may be associated with TAPVC and a small RV may be associated with tricuspid atresia.

Some tips for identifying common cardiac problems in children are given in Table 1.

**CONCLUSION**

Basic echocardiography is an important tool for making a quicker diagnosis and better management of children suffering from cardiac problems. The ultrasonography machine should be easily available in emergency and ICU areas and the pediatric residents should be trained in the skills of basic echocardiography to recognize cardiac ailments in children. They should be trained in recognizing most of the common cardiac problems. One of the simpler versions of this training is subcostal view

echocardiography which they should be trained in, as it helps in imaging most of the common and critical cardiac lesions by manipulating probe at one place. Considering its wider applicability in improving patient care, basic echocardiography training should be included in the curriculum of pediatric junior residency.

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