

A systematic approach to epicardial echocardiography in pediatric cardiac surgery: An important but underutilized intraoperative tool

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ABSTRACT

Intraoperative echocardiography is an integral component of the peri-operative management of pediatric heart disease. It confirms the adequacy of surgery, identifies residual lesions, and can provide useful hemodynamic data. It, therefore, helps to decide on the need for revision of repair and guides the postoperative management strategy. Intraoperative echocardiography is done with the use of either an epicardial probe or a transesophageal probe. Epicardial echocardiography is a simple, useful modality and has the ability to perform imaging in cases where transesophageal echocardiography cannot be easily performed, for example, in low birth weight babies. We attempt to describe in detail the technique of epicardial echocardiography and the various views that we have found useful for a complete postsurgical evaluation. The limitations of the technique are also discussed in detail.

Keywords: Epicardial echo, postoperative echo, residual defects, transesophageal echocardiography

INTRODUCTION

Intraoperative echocardiography is an important tool in the armamentarium of the surgeon. Echocardiographic assessment of the surgical repair on the surgical table at the end of surgery confirms not only the adequacy of repair but it also provides important information that helps titrate vasoactive and inotropic supports after cessation of cardiopulmonary bypass. More importantly, the timely detection of residual or previously undetected defects allows for remedial action at the same time, thereby eliminating a major cause of postoperative morbidity, mortality, and prolonged intensive care unit stay. Hospital resources are conserved and this is an important consideration in resource-limited environments.

Two diagnostic modalities are currently available for intraoperative echocardiography: transesophageal echocardiography (TEE) and epicardial echocardiography (EpiEcho). Although EpiEcho was the first modality to be used intraoperatively,^[1,2] it became unpopular with the advent of TEE.^[3,4] Most surgical teams worldwide now rely on intraoperative TEE. However, TEE necessitates the purchase of expensive TEE probes and the availability of a sonographer trained in the use of intraoperative TEE. Epicardial echocardiography on the other hand utilizes standard transthoracic probes and requires no additional skills other than knowledge of basic echocardiographic techniques.

This is of immense relevance to pediatric cardiac units in low- and middle-income countries which do a high

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volume of congenital heart repairs but are constantly struggling with financial and manpower constraints.^[5]

EpiEcho has been the routine in our institution for the past 22 years and our experience extends to over 9000 EpiEcho examinations in this period of time.^[6] EpiEcho is performed on all patients undergoing cardiac surgery through a mid-sternotomy incision. Evaluation of ventricular function forms an important component of every study.

Based on our experience, we feel that a systematically performed EpiEcho has many advantages over TEE and should be more widely utilized. We also describe a few additional views that we have found useful but are not hitherto described in the literature.^[7,8]

TRANSESOPHAGEAL VERSUS EPICARDIAL ECHOCARDIOGRAPHY

TEE has been energetically promoted as the procedure of choice for intraoperative echocardiography even in neonates – with the introduction of the miniaturized (albeit expensive) neonatal TEE probe. However, despite its overwhelming popularity and its published favorable influence on peri-operative clinical decision-making and eventual outcomes, TEE has limitations and a small but definite incidence of complications,^[9-11] as enumerated below [Table 1]:

- TEE imaging of some cardiac structures, e. g., the distal ascending aorta and aortic arch or right ventricular outflow tract (RVOT) and pulmonary artery (PA) bifurcation may be impaired by the interposition of the trachea and main bronchi and is therefore suboptimal
- The TEE probe may occasionally be difficult or impossible to advance into the esophagus, and in patients with significant gastroesophageal pathology, the placement of a TEE probe may even be contraindicated
- TEE may result in perioperative morbidity from oropharyngeal and gastroesophageal injury-causing dysphagia, gastrointestinal hemorrhage, or even rarely gastroesophageal rupture
- The TEE probe has to be inserted before administration of heparin to the patient and it continues to be in place for the entire length of the surgery. If an unplanned study is required in a heparinized patient then there is risk of bleeding
- Then probe may suffer thermal damage during the rewarming phase of cardiopulmonary bypass. TEE probes are expensive, fragile, and require disinfection or sterilization before use. In a busy surgical unit, if multiple patients need to be evaluated, then multiple probes need to be available. Additional costs are also incurred in software upgrades and need for special storage facilities.

Epicardial echocardiography, on the other hand, was introduced as a diagnostic imaging modality to assist cardiac surgeons with intraoperative decision-making, more than a decade before the advent of TEE. A comprehensive epicardial echocardiographic examination can be performed efficiently and safely in almost any situation and in any size of patient.^[12,13] Some of the notable advantages of this technique are:

- It is the only practical intraoperative imaging technique possible when a TEE probe cannot be inserted or when probe placement is contraindicated
- EpiEcho provides more optimal image resolution when using higher frequency probes
- EpiEcho offers better windows for imaging anterior cardiac structures including the aorta, aortic valve (AV), pulmonary valve, and pulmonary arteries including the PA bifurcation and therefore is more useful in the evaluation of these structures^[9]
- It requires no additional equipment other than what is available in a standard echocardiography unit
- The surgeon can direct the views to interrogate the areas of the heart that he/she is most concerned about. The procedure can, therefore, be more goal directed. There is also less dependency on the availability of a trained echocardiographer^[12]
- Concerns have been raised that the use of epicardial imaging predisposes to mediastinal infection due to potential cracks in the sterile sleeve cover. When a proper technique as described here is used, the risk of infection is low and possibly lesser than with a transesophageal probe that is placed in the GI tract, and reused repeatedly after disinfection, without being covered in a sterile sleeve. In resource-limited but busy units, sterility may be compromised when multiple TEE studies need to be performed with limited time for adequate disinfection between the cases.

EpiEcho also has some limitations. First, it can only be performed when the heart is exposed surgically. However, whenever the heart is exposed through sternotomy, epicardial imaging has a clear advantage. An argument often put forward against EpiEcho is that it requires interruption of the surgical procedure for imaging and so does not permit continuous echocardiographic monitoring.^[9] However, in most instances, meaningful evaluation of the surgical repair is done only when cardiopulmonary bypass has been discontinued and stable hemodynamics have been achieved. The need for interruption of the surgical procedure, therefore, is not a tenable argument. Sometimes, the heart may be irritable and hemodynamic instability may preclude a detailed study. Patience and gentle handling of the probe often yields the desired result. With an enlarged heart, sometimes, true apical views may be difficult because of an inability access to the true apex of the heart.

The American Society of Echocardiography Council for Intraoperative Echocardiography has proposed a set of seven standardized and comprehensive views for epicardial examination.^[11] We have used these routinely and in addition defined some more views which we feel provide for a more comprehensive study. The setup for epicardial imaging and the specific imaging views for evaluating specific areas of the heart and great vessels is described in the following narrative.

TRAINING GUIDELINES

There are no well-defined guidelines for training in EpiEcho in our country. ASE guidelines state that before a trainee should pursue independent interpretation and application of the information to peri-operative clinical decision-making, he or she should perform at least 25 epicardial examinations of which five are personally directed under the supervision of an advanced echocardiographer.^[14]

EPICARDIAL PROBE PREPARATION AND METHODOLOGY

Epicardial echocardiography involves the placement of the transducer, encased in a sterile polyethylene sleeve, over the surface of the heart, for the acquisition of two-dimensional, color flow, and spectral Doppler images in multiple planes. The hardware includes:

1. An echocardiography machine with requisite transthoracic probes (5–12 MHz) [Figure 1a]. For neonates and infants, probes with the smallest footprint should be available
2. A sterile polyethylene sheath that is about 150 cm long and 8–10 cm wide and sealed at one end [Figure 1b]
3. A sterile rubber band (which may be prepared on the table using the wrist portion of latex gloves) [Figure 2a]
4. Two artery forceps.

The setup involves the following steps:

- The surgeon places an additional sterile drape over the anesthesia screen at the head and of the operation table as shown in Figure 2b
- The surgeon clips the open end of the sterile sheath with an artery forceps and passes it to the echocardiographer at the head end of the table over the anesthesia screen
- The echocardiographer fixes the edge of the sheath to the surgical drape on the other side of the screen with the second artery forceps so that the unsterile portion of the sheath does not slide back into the surgical field during manipulation [Figure 2b]
- The transducer probe tip is coated with a blob of sterile acoustic jelly and is slid into the sterile sheath.



Figure 1: Hardware used for epicardial echocardiography. (a) The probes that are commonly used for the echocardiography generally have the smallest footprint compatible for the patient. In the present case, 12 MHz and 8 MHz frequency that are commonly used in our unit are being displayed. (b) The sterile sheath for the probe

The surgeon then grips the transducer with the sterile sheath and threads it down the remaining length of the sheath till an adequate length of the transducer is available for a comfortable study. The echo machine often has to be moved close to the head end of the table to achieve this. The sealed end of the sheath is then tightly folded over the tip of the transducer ensuring that there is no air bubble trapped and fixed in place with several loops of the rubber band. The study can now be performed by placing the probe on the epicardial surface of the heart. Sterile saline solution can be poured into the pericardial cavity to further enhance acoustic transmission from the probe to the epicardial surface.

The technique described above is designed to maintain sterility and also ensure that there is adequate jelly over the probe. The depth setting and the depth of transmit focus is then adjusted to visualize the near field. If a multifrequency probe is used, the frequency is increased to obtain the highest resolution image possible.

The surgeon obtains the images by appropriately manipulating the echocardiographic probe in the sterile arena and the image setting may be adjusted by the echocardiographer in the unsterile field. The images are seen and interpreted by them together. It is important to have a fluid interface between the probe and the heart. It is for this reason that the end of the probe is frequently wetted with squirts of saline to have optimum imaging.

Most of the views display the cardiac structures in the same orientation as the surgeon would view them intraoperatively and differ from the conventional views obtained in a standard transthoracic or transesophageal examination.

Imaging planes

For better understanding, we have listed the predominant structure that each specific view interrogates. Most of the

evaluation is done with the probe placed at a single spot over the free wall of the right ventricle (RV). The long axis is marked in Figure 3. Rotation and tilting of the probe along the described axis enables imaging in the various views that are required for a complete evaluation. The only view requiring a change of probe position is the transaortic view where the probe is placed across the ascending aorta.

Long-axis view

The echocardiographic probe is angled superiorly with marker pointing toward the patient's right shoulder to generate the epicardial long-axis view (LAX) view along the long axis of the heart [Figure 4a]. The echo probe is placed at the junction of the anterior and inferior surface of the heart. The probe is then gradually angled toward the patient's right shoulder. This view allows visualization of the inferolateral and anteroseptal walls of the left ventricle (LV) and the RV, left atrium (LA), left ventricular outflow tract (LVOT), AV, and mitral valve (MV) [Figure 4b]. Color Doppler interrogation of the AV and MV is possible in this view. With posterior and anterior tilt, different structures may be visualized as described below:

- Long axis: (without tilt) displays the interventricular septum, left ventricular outflow, AV, and the proximal part of the ascending aorta [Figure 4b]



Figure 2: The steps for the epicardial probe placement. (a) The use of the ring from a sterile glove to secure the sheath over the end of the probe. (b) The placement of the sterile sheath (arrow) and the placement of the artery forceps toward the echocardiographer's end. Similar forceps is attached toward the surgeons' end to prevent slippage of the sheath

- Long axis with leftward tilt [Figure 4c] displays the left ventricular inflow and pulmonary veins
- LAX with rightward tilt [Figure 5a] allows for the evaluation of the right atrium and right ventricular inflow [Figure 5b and c]. Spectral Doppler evaluation of the inflows may be done in this view. The rightward motion of the probe with marker oriented superiorly (12-o'clock) so that the transducer overlies the right atrium with marker oriented inferiorly shows a bicaval view of the systemic venous return and the atrial septum.

Apical 4-chamber view

The apical 4-chamber view is obtained by sliding the probe toward the apex [leftward from the position in Figure 4a] and orienting the probe rightward and posteriorly toward the inflows [Figure 6a]. The Doppler evaluation of both the valves may be done in this view. This view is important for both the inflows and interventricular septum evaluation [Figure 6b]. It is at times difficult to keep the probe stable at the apex. In such a scenario, the probe may be kept over the anterior surface of the RV (as close to the apex as possible) and oriented rightward and posteriorly. At times, the sternal retractor needs to be stretched to open up the sternum to expose the apex for this view. The heart may also be gently lifted up with a sponge in the pericardial cavity to improve access to the apex.

The probe position directed further posteriorly may be useful not only to demonstrate TV inflow but also to investigate the coronary sinus [Figure 6c].

Parasternal short-axis view (equivalent)

- The RVOT view: This is obtained by sliding the transducer over the RVOT which is mostly on the anterior surface of the anterior ventricle and directing the transducer anteriorly with

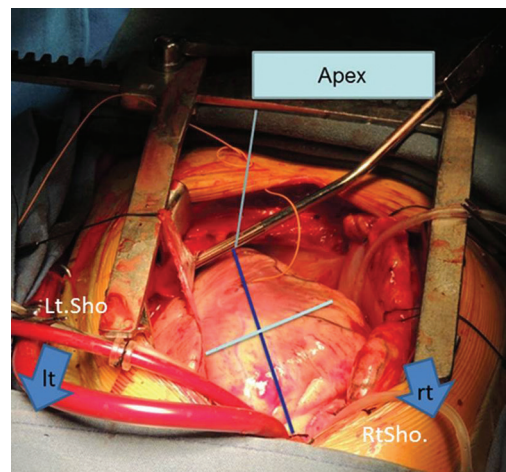


Figure 3: The orientation of the heart on the surgical table. The apex of the heart has been labeled. The long axis of the heart is drawn from the apex to the base (blue line) and short axis of the heart (white line). The position of the right shoulder (Rt Sho) and the left shoulder (Lt Sho) has been labeled for orientation

marker toward the left shoulder [Figure 7a]. Orienting a spectral Doppler beam parallel to blood flow permits the evaluation of RVOT. The RVOT, pulmonary valve, and proximal main PA can be visualized. Color flow Doppler can then

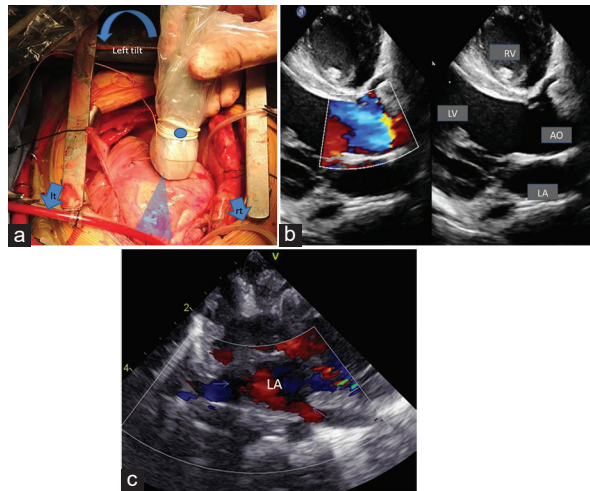


Figure 4: The long axis of the heart. (a) The probe position for making the long axis of the heart. The probe can be tilted in the left or right direction to visualize structures (marked by arrow). (b) The LAX. The position of the marker of the probe is directed toward the right shoulder (marked by circle). Right (Rt) and left (Lt) shoulders' direction is shown by the broad arrows. (c) Color flow interrogation of the LA demonstrating laminar flow in pulmonary veins (marked by arrow). LAX: Long-axis view, LA: Left atrium

- b. Short-axis view (SAX) distal RVOT view: The transducer is directed toward the patient's left and slid superiorly. The transducer typically has to be rotated clockwise by approximately 30° from the LAX to develop this view [Figure 8a]. The marker faces the patient's left and the transducer beam is directed in the rightward direction. The right coronary cusp will be at the top of the monitor screen, the left coronary cusp will be on the right, and the noncoronary cusp will be on the left side of the screen adjacent to the interatrial septum [Figure 8b]
- c. Short axis with anterior tilt: Mild anterior tilt from this view identifies the RVOT including PA and proximal RVOT [Figure 9a and b]. With color

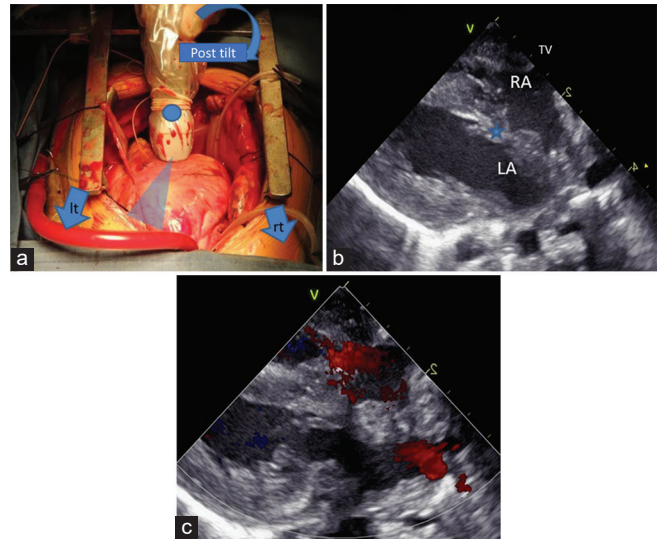


Figure 5: (a) The position of the probe for the long axis of the heart with the posterior tilt to demonstrate tricuspid valve inflow. (b) Two-dimensional echocardiography of the long axis with right tilt. (c) Color flow mapping of the inflows: Tricuspid valve, RA: Right atrium, IAS (marked by arrow): Interatrial septum is marked by the star

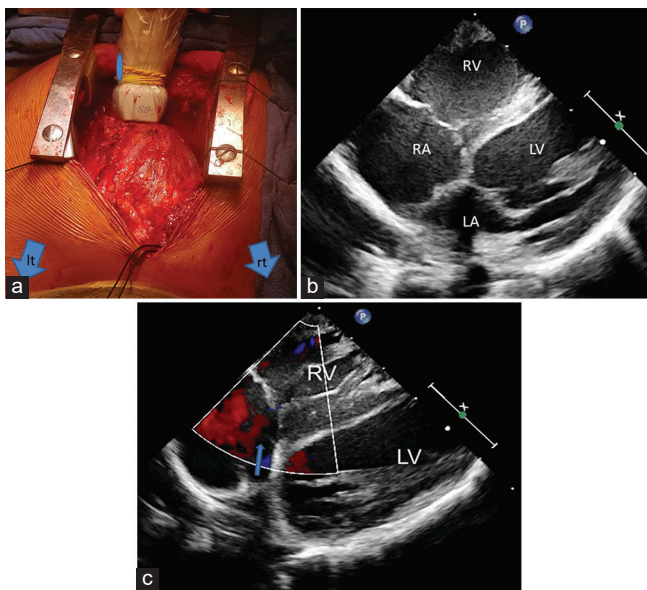


Figure 6: The 4-chamber view. (a) The probe placement for the view. The marker on the probe is toward the right. The probe is kept close to the apex of the heart and oriented posteriorly for inflow. The broad marker shows the inclination on the probe to demonstrate the image. (b) The 4-chamber view in true apical 4-chamber view. LV: Left ventricle, RV: Right ventricle, LA: Left atrium, RA: Right atrium. (c) Demonstrating posterior tilt to the plane of the tricuspid valve to show the opening of the coronary sinus (marked by arrow)

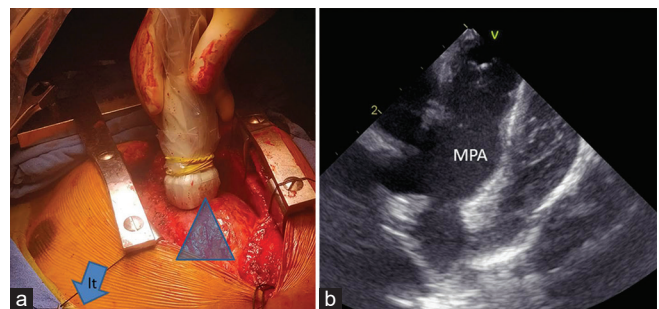


Figure 7: RVOT view. (a) the transducer is placed over the anterior ventricular surface with marker toward the left shoulder orienting the spectral beam parallel to the RVOT. (b) The orientation of the RVOT and the MPA with respect to the view obtained in the RVOT view. RVOT: Right ventricular outflow tract, MPA: Main pulmonary artery

Doppler, this view may be used to demonstrate pulmonary stenosis or regurgitation. Doppler evaluation is used to quantitate the gradient across the RVOT [Figure 9c]

- d. Short axis with apical sweep: With the probe directed toward the patient's left (marker toward the left) and a sweep from the base to the apex, the whole of the interventricular septum can be scanned to look for muscular ventricular septal defects (VSDs) [Figure 10a-c]. Left ventricular function is well seen as well as areas of regional dysfunction. The MV and subvalvular apparatus can also be evaluated in the SAX [Figure 10d].

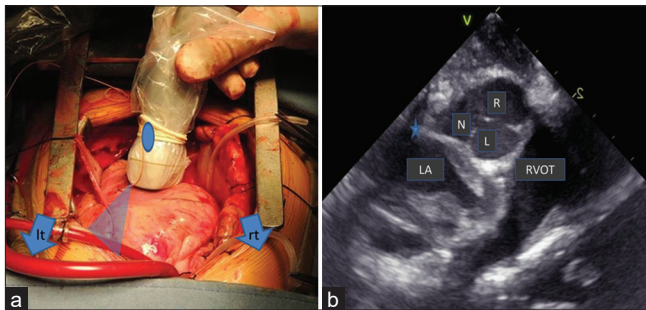


Figure 8: The beginning of the RVOT, and aortic valve cross-section. (a) Surgical image showing the probe position for obtaining the image with marker of the probe oriented to the left along the RVOT. (b) Echocardiographic image showing the RVOT and short axis of the aortic valve. RVOT: Right ventricular outflow tract

Transaortic view

Transaortic views are obtained by keeping the transducer directly on the proximal ascending aorta.

- a. Transaortic view (short axis): The transaortic SAX is obtained by positioning the transducer on the ascending with a marker toward the right [Figure 11]. The ultrasound beams transverse the base of the

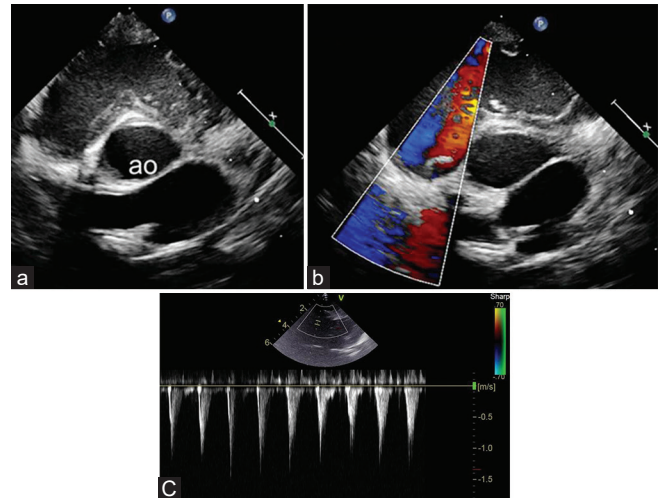


Figure 9: The RVOT. Modified parasternal short axis to profile the right ventricular outflow tract. (a) View to demonstrate the RVOT from mild anterior and clockwise tilt from position 8a to demonstrate the RVOT. (b) The color comparison of the same. (c) The Doppler signal across the RVOT. RVOT: Right ventricular outflow tract

Table 1: The comparison of the epicardial echocardiography and transesophageal echocardiography

Intraoperative TEE

TEE necessitates the purchase of expensive TEE probes

TEE imaging of some cardiac structures, e.g., the distal ascending aorta, aortic arch or right ventricular outflow tract, and pulmonary artery bifurcation may be impaired by the interposition of the trachea and main bronchi and is therefore suboptimal

Uses standard views

Dependent on availability of sonographer trained in the use of intraoperative TEE

It is more difficult to align Doppler signals for certain structures (such as right ventricular outflow and branch pulmonary arteries) in order to assess the accuracy of repair

TEE probe can be potentially damaging in neonate and infants when it is kept in the esophagus for long periods

TEE may also result in perioperative morbidity from oropharyngeal and gastroesophageal injury-causing dysphagia, gastrointestinal hemorrhage, or even rarely gastroesophageal rupture

TEE cannot be performed in babies weighing <3.5 kg

TEE probe may occasionally be difficult or impossible to advance into the esophagus, and, in patients with significant gastroesophageal pathology, the placement of a TEE probe may even be contraindicated. The TEE probe has to be inserted before administration of heparin to the patient and it continues to be in place for the entire length of the surgery. If an unplanned study is required in heparinized patient, there may be risk of bleeding

TEE: Transesophageal echocardiography

Epicardial echo

It requires no additional equipment other than what is available in a standard echocardiography unit

EpiEcho provides more optimal image resolution when using higher frequency probes

Can image these structures very clearly

The surgeon can direct the views to interrogate the areas of the heart that he/she is most concerned about. The procedure can therefore be more goals directed. There is also lessened dependency on the availability of a trained sonographer

Ability to align the Doppler signals by freely moving the transducer to get accurate gradients

No such risk

Can easily be performed

It is the only practical intraoperative imaging technique possible when a TEE probe cannot be inserted or when probe placement is contraindicated

Can be done as and when needed during surgery

heart thus obtaining the images from the outflows. With appropriate tilt of the probe, the PA bifurcation and proximal branch pulmonary arteries can be nicely visualized and also the SAX of the ascending aorta [Figure 12]. While the right PA is visualized coursing transversely beneath the aorta, the left PA is seen going away from the transducer probe. This view has a distinct advantage over TEE in imaging the PA bifurcation in situations where repair of the left PA has been performed

- b. **Transaortic LAX:** The transaortic LAX is obtained from the base of the heart (as described for SAX) with the transducer rotated by about 50°–90° from the SAX in an anticlockwise motion. The transducer is along the long axis of the heart [Figure 13]. The structure which is well identified in this view is the arch and the descending aorta [Figures 14 and 15]. When there is a right aortic arch, the marker of the probe is pointed in the direction of the right shoulder to get the same view

To summarize the various views, suggested are listed below [Table 2]:

1. LAX
 - Long axis with leftward tilt shows LV, LVOT, and AV
 - LAX with rightward (posterior) tilt
2. Four-chamber view
 - Four-chamber view with mitral and tricuspid valve inflow
 - Four-chamber view with posterior tilt
3. Parasternal SAX (equivalent)
 - RVOT view

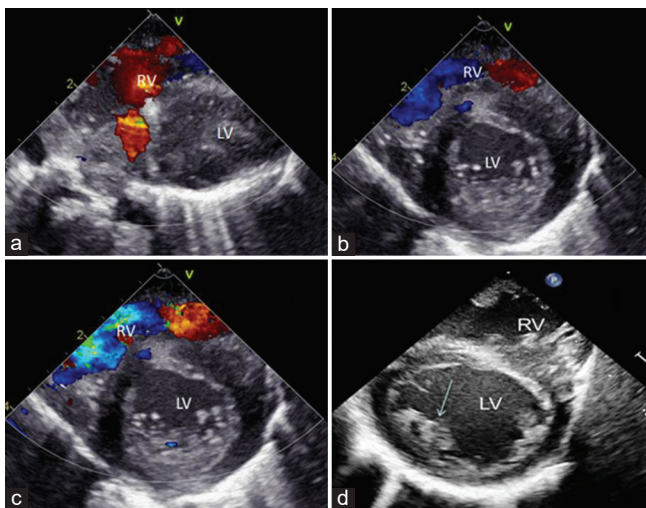


Figure 10: (a-c) Two-dimensional echocardiography with color flow mapping in short-axis view showing the screening of the interventricular septum from the apex (a) to the base of the heart (b and c). The screening is being done to investigate for the presence of additional VSD. (d) Short axis at the level of the papillary muscle (marked by arrow) to investigate the subvalvular apparatus. RV: Right ventricle, LV: Left ventricle, VSD: Ventricular septal defect

- Short-axis distal RVOT view
 - Short axis with anterior tilt
 - Short axis with apical sweep
4. **Transaortic view:**
 - Short axis
 - Long axis.

Patch closure of ventricular septal defect

In doubly committed or perimembranous defects, a short-axis view with the transducer over the right ventricular free wall will demonstrate a residual defect and offer an opportunity for Doppler interrogation. The long axis may show the patch in other views. Short axis is important to demonstrate the left ventricular function [Table 3].

Intracardiac repair of tetralogy of Fallot

EpiEcho is preferable to TEE. The long axis and SAXs are used to interrogate the VSD patch and the RVOT view is used to assess the adequacy of the outflow resection. The transaortic view is used to display the branch pulmonary arteries [Table 3].

Total anomalous pulmonary venous return

EpiEcho is preferred over TEE because of the possibility

Table 2: The intracardiac structures and the appropriate views in which they can be profiled

Structure	View
Interatrial septum	Long-axis view, 4C view
Left atrium+supramitral structure	Long-axis view 4C view, short axis with anterior sweep
Mitral inflow	Long-axis view/4C view
Interventricular septum (VSD)	Parasternal short-axis view with sweep
TV inflow	Long axis with posterior tilt, apical 4C view
RVOT	RVOT view
Branch PAs	Transaortic short-axis view
Arch and aorta	Transaortic long-axis view

VSD: Ventricular septal defect, RVOT: Right ventricular outflow tract

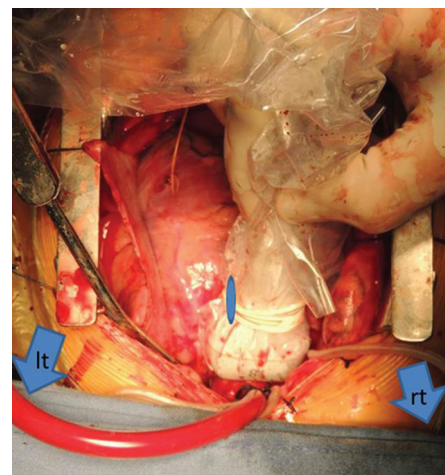


Figure 11: Epicardial; imaging showing the probe positioning across the base of the heart for the transaortic short-axis view. Note the marker is on the left side and the probe is positioned perpendicular to the axis of the heart. Over the great vessels

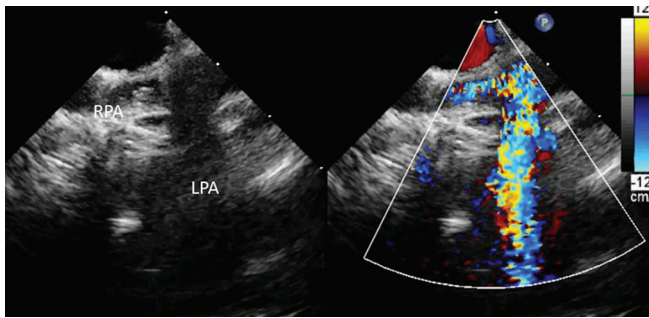


Figure 12: Two-dimensional echocardiography with color Doppler in transaortic short-axis view with branch pulmonary arteries. LPA: Left pulmonary artery, RPA: Right pulmonary artery

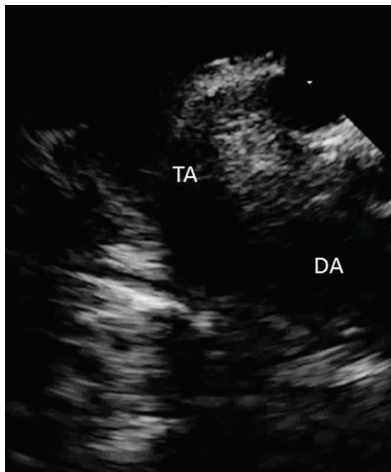


Figure 14: Two-dimensional echocardiography in transaortic long-axis view with descending aorta in a patient with right aortic arch. TA: Transverse arch, DA: Descending aorta

of compression of pulmonary venous confluence posteriorly by the transesophageal probe.^[4] The anastomosis and individual pulmonary veins can be viewed from short- and long-axis views. The transducer is placed over the right ventricular outflow or free wall and angled to image the anastomosis between the LA and the confluence in multiple planes.

Arterial switch operation for transposition of the great arteries

Visualizing the branch pulmonary arteries by TEE can be challenging due to their anterior position after the Le'compte maneuver. The area of interest is predominantly valvar and supravalvular, so epicardial echo is superior. With transducer placement directly over the right ventricular outflow and orientation of the index marker along the long axis of the outflow, the aortic and pulmonary valves as well as the neopulmonary and neo-aortic anastomosis can be imaged. Apical view with cranial angulation will align the transducer with the outflows with the transducer over the PA bifurcation; the branch pulmonary arteries can also be imaged. Imaging of the coronary anastomoses and demonstration of flow in the coronary arteries is possible as well. Left ventricular

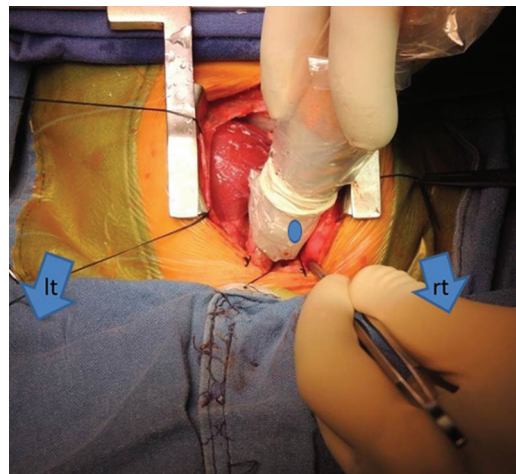


Figure 13: Epicardial; imaging showing the probe positioning across the base of the heart for the transaortic long-axis view. The transducer gets rotated by about 50°–90° from the short-axis view to align it parallel to the long axis of the heart

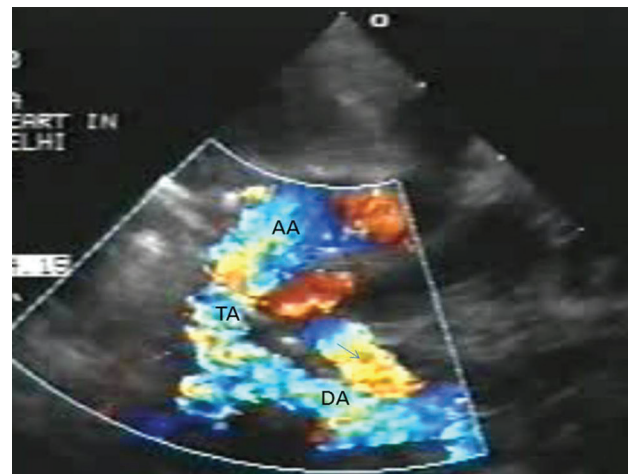


Figure 15: Two-dimensional echocardiography with the color flow mapping in a patient of coarctation of the aorta after repair showing the well-opened arch segment with good flow across the arch. Flow across the right pulmonary artery can be seen (marked by arrow). AA: Ascending aorta, TA: Transverse arch, DA: Descending aorta

Table 3: The various lesions and the appropriate views in which they are profiled

Lesion	View
ASD	Long-axis view, 4C view
TAPVC confluence in relation to LA	Long-axis view, 4C view
Cor triatriatum	Short-axis view
Mitral valve anomalies	Long-axis view, 4C view, Short-axis view
Subvalvular apparatus of mitral valve	Short-axis view
LV function	Short-axis view
Subvalvular+valvular aortic stenosis	Long-axis view
Subvalvular+valvar pulmonary stenosis	RVOT view
Branch PA stenosis	Transaortic short-axis view
Coarctation	Transaortic long-axis view
Glenn shunt	Transaortic long-axis view

ASD: Atrial septum defect, TAPVC: Total anomalous pulmonary venous connection, LA: Left atrium, LV: Left ventricle, PA: Pulmonary artery, RVOT: Right ventricular outflow tract

function and regional wall motion abnormality may be seen in SAX. A few examples of residual defects picked up on epicardial echo are shown in Videos 1-5.

CONCLUSION

Epicardial echocardiography is a resource-effective evaluation tool on the surgical table. Besides the evaluation of certain preprocedural surgical queries, its most important utility is the evaluation of a postoperative patient. The imaging views can be tailored to the respective lesion and its anticipated problems and residual lesions. The assessment of the residual lesion enables the surgeon to decide for a reoperative strategy and also to anticipate the possible problems in the immediate postoperative period. On the other hand, confirmation of an adequate repair allows the intensive care team to better plan the postoperative care.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Hagler DJ, Tajik AJ, Seward JB, Schaff HV, Danielson GK, Puga FJ, *et al.* Intraoperative two-dimensional Doppler echocardiography. A preliminary study for congenital heart disease. *J Thorac Cardiovasc Surg* 1988;95:516-22.
2. Ungerleider RM, Greeley WJ, Sheikh KH, Kern FH, Kisslo JA, Sabiston DC Jr, *et al.* The use of intraoperative echo with Doppler color flow imaging to predict outcome after repair of congenital cardiac defects. *Ann Surg* 1989;210:526-33.
3. Rice MJ, Sahn DJ. Transesophageal echocardiography for congenital heart disease--who, what, and when. *Mayo Clin Proc* 1995;70:401-2.
4. Shiota T, Lewandowski R, Piel JE, Smith LS, Lancée C, Djoa K, *et al.* Micromultiplane transesophageal echocardiographic probe for intraoperative study of congenital heart disease repair in neonates, infants, children, and adults. *Am J Cardiol* 1999;83:292-5, A7.
5. Nguyen N, Leon-Wyss J, Iyer KS, Pezzella AT. Paediatric cardiac surgery in low-income and middle-income countries: A continuing challenge. *Arch Dis Child* 2015;100:1156-9.
6. Kaushal SK, Dagar KS, Singh A, Kumar K, Radhakrishnan S, Girotra S, *et al.* Intraoperative echocardiography as a routine adjunct in assessing repair of congenital heart defects: Experience with 300 cases. *Ann Card Anaesth* 1998;1:36-45.
7. Eltzhig HK, Kallmeyer IJ, Mihaljevic T, Alapati S, Shernan SK. A practical approach to a comprehensive epicardial and epiaortic echocardiographic examination. *J Cardiothorac Vasc Anesth* 2003;17:422-9.
8. Stern KW, Emani SM, Peek GJ, Geva T, Kutty S. Epicardial echocardiography in pediatric and congenital heart surgery. *World J Pediatr Congenit Heart Surg* 2019;10:343-50.
9. Muhiudeen IA, Roberson DA, Silverman NH, Haas G, Turley K, Cahalan MK, *et al.* Intraoperative echocardiography in infants and children with congenital cardiac shunt lesions: Transesophageal versus epicardial echocardiography. *J Am Coll Cardiol* 1990;16:1687-95.
10. Stevenson JG. Incidence of complications in pediatric transesophageal echocardiography: Experience in 1650 cases. *J Am Soc Echocardiogr* 1999;12:527-32.
11. Ayres NA, Miller-Hance W, Fyfe DA, Stevenson JG, Sahn DJ, Young LT, *et al.* Indications and guidelines for performance of transesophageal echocardiography in the patient with pediatric acquired or congenital heart disease: Report from the task force of the Pediatric Council of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2005;18:91-8.
12. Manvi VF, Dixit M, Srinivas K, Vagarali A, Patil S, Manvi NG. Accuracy of intraoperative epicardial echocardiography in the assessment of surgical repair of congenital heart defects confirmed. *J Cardiovasc Echogr* 2013;23:60-5.
13. Ungerleider RM, Greeley WJ, Kanter RJ, Kisslo JA. The learning curve for intraoperative echocardiography during congenital heart surgery. *Ann Thorac Surg* 1992;54:691-6.
14. Reeves ST, Glas KE, Eltzhig H, Mathew JP, Rubenson DS, Hartman GS, *et al.* Guidelines for performing a comprehensive epicardial echocardiography examination: Recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr* 2007;20:427-37.