Intraoperative use of echocardiography has become an integral part of the management of children and adults undergoing surgical repair of congenital cardiac defects. Initially, epicardial echocardiography was the only method available to perform imaging in the smaller children. In 1989, the first report of using a miniaturized single plane adult TEE probe in a 7 year old child (1), demonstrated the advantages of TEE. Compared to epicardial echocardiography, TEE does not interfere with or delay the surgical procedure, increase the risk of arrhythmias and infection, and can be performed continuously, as well as in the postoperative period. However, the use of a single plane TEE probe failed to identify anterior structures, especially the right ventricular outflow tract. Several companies have succeeded in developing pediatric-size, multiplane TEE probe, that are currently in clinical use in very small children. Compared to the adult probes, a pediatric multiplane TEE probe has a gastroscope diameter of 7 mm, a tip of 9x8 mm, and a frequency of 5 to 7.5 MHZ.

The training of physicians in pediatric TEE has the two main goals of achieving technical skills of imaging and interpretation ability. The current recommendations are the performance of 300 studies for basic training, 400 for advanced and 750 for independent practice, with at least 50% of these cases in patients smaller than 1 year old (2). A recent study demonstrated that patient outcome is affected beneficially when pediatric intraoperative TEE is performed by physicians who meet the training guidelines, and whose sole responsibility is the performance of echocardiography (3). Significantly more children had adequate TEE studies, more residual defects were detected and managed by return to bypass.

Several reports have demonstrated the precautions that should be taken when performing TEE in children. Due to a higher risk of loose teeth, coagulopathy with cyanotic heart disease, and vertebral abnormalities, caution in the insertion and advancing of the TEE probe should be taken. In addition, the relative size of the probe to the smaller infant may cause vascular occlusion, airway obstruction, accidental extubation, or endobronchial advancement of the endotracheal tube (4). However, a recent prospective study reported no significant changes in ventilation variables, in 22 infants, 2-5 kg, undergoing TEE during cardiac surgery (5).

The basic echocardiographic examination in children with congenital cardiac defects identifies the cardiac situs, the anatomic structures and the communications (6). The cardiac situs is identified by the axis of the heart, and the relation of the great vessels to the vertebral column.

**Venous connections:** To identify the SVC, IVC connection to the right atrium, both the longitudinal and transverse views are needed. It is also essential to document the size of the coronary sinus at the base of the left atrium, to rule out the presence of a left SVC. A normal CS should be less than 30% of the LA size. The presence of a LSVC will change the plans for percutaneous as well surgical cannulation for cardiopulmonary bypass. The pulmonary venous drainage should be identified bilaterally, especially in the presence of an atrial septal defect.
Anatomic structures: The atrio-ventricular and ventriculo-arterial connections have to be documented to reach an adequate diagnosis. Thus the different structures are identified using specific landmarks on TEE.

To identify the atrial anatomy, the appendages of the RA and LA can be examined for differences in appearance. The RAA is best seen in the basal short axis view, as a short, blunt structure with a broad junction to the RA and a rudimentary Eustachian valve at the mouth of the IVC. The LAA is seen in the four chamber view as a long, crenelated structure with a narrow junction to the LAA and the possible presence of a membrane dividing the LA (cor triatriatum).

The ventricles also have distinctive morphologic appearances. The RV has a triangular cavity with a trabeculated, endocardial surface and a moderator band. The RV is always attached to the more broad, trileaflet, apically positioned tricuspid valve with three papillary muscles and septal chordae. The thicker LV has an ellipsoid cavity, with a smooth endocardial surface and two papillary muscles. The LV is always attached to the bileaflet, basally inserted mitral valve.

The great vessels can be identified by their position and branching. The pulmonary artery is anterior and leftward with a short MPA dividing into two branches. The aorta is posterior and rightward, with a longer ascending aorta, and coronary arteries originating at the sinuses.

Cardiac Crux: The interatrial septum is best seen in two planes to avoid the misleading appearance of a drop-off as a defect. The IAS may have a defect in the area of the fossa ovalis (secundum ASD), the more basal area of the atroventricular valves (primum ASD), or the more inferior (sinus venosus ASD) with abnormalities in pulmonary venous drainage.

The interventricular septum may also have a defect in either the muscular, perimembranous or subarterial areas, and must be examined in more than one plane to correctly identify defects.

Doppler examination is an essential component of a complete pediatric TEE study. Using CFD, PW and CWD, information on shunt amount and direction, degree of obstruction and vascular resistance can be obtained (7). Using doppler interpretation, several methods were identified, and validated by cardiac catheterization results, to calculate pulmonary-to-systemic shunt flow through a VSD. One such method uses the flow through the PA and the aorta and the continuity equation:

\[ \frac{Qp}{Qs} = \frac{\text{Area PA} \times \text{VTI}}{\text{Area Ao} \times \text{VTI}} \]

In addition, the degree of pulmonary hypertension can be identified using doppler examination of the pressure gradient between the LV and RV through a VSD, and the systemic arterial pressure, or using the jet of TR and the RA pressure (8).

The benefits of TEE in children with congenital heart disease, are to improve accuracy of diagnosis, use as an intraoperative monitor and identification of residual defects following a repair.

Intraoperative TEE is essential to confirm the preoperative diagnosis and the planned surgical procedure. In 8.5% of patients, TEE either added important information, or significantly changed the surgical approach in children with a cardiac defect. In fact, the use of TEE in the very small infants, had an equal accuracy to cardiac catheterization,
with significant decrease in morbidity and mortality, comparing children with similar diagnoses (9).
Intraoperatively, TEE is a valuable monitor of cardiac function and ventricular filling, that will help in the management of fluids and inotropic support. In a study of 7 patients with transposition of the great arteries following an atrial switch, who were undergoing pulmonary artery banding to train the LV to become the systemic ventricle, TEE was a valuable tool to guide the degree of tightening of the PA band (10). These patients had no intracardiac shunts, so the pulse oximeter had a limited ability to direct the surgical procedure.
Following surgical repair of congenital cardiac defects, patients with residual lesions identified by TEE, had a longer hospital length of stay, a worse postoperative functional status, and a higher mortality compared to patients with no residual defects (11). In those patients whose residual lesions were immediately identified by TEE and managed in the same surgical encounter, the outcome as well as the cost of care was significantly improved (12).

REFERENCES: