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Transesophageal echocardiography in congenital heart surgery: Perioperative considerations

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ABSTRACT

Transesophageal echocardiography plays an integral role in modern congenital cardiac surgery. Perioperative details such as probe selection, proper insertion technique, and concurrent hemodynamic monitoring are often underemphasized, but have a significant impact on patient safety in the operating room. Herein, we provide an in-depth review of transesophageal echocardiography probe selection and placement techniques, contraindications, and management of equipment in the operating room. Minimizing the risks involved with transesophageal echocardiography should be a goal for every cardiac surgical team.

1. Introduction

Intraoperative transesophageal echocardiography (TEE) allows for real-time uninterrupted imaging of cardiac structures and function during congenital heart surgery and reduces the morbidity, mortality and cost related to these procedures [1–4]. Since the initial report of using the esophagus as a site of imaging by Frazin et al. in the mid 1970's, there has been enormous advancement in TEE echocardiography probe miniaturization and image quality as well as in the evolution of platform technology allowing infants as small as 1.4 kg to benefit [5,6]. Most congenital heart centers routinely utilize intraoperative TEE to confirm preoperative diagnoses and alter surgical plans if additional lesions are noted, ensure cardiac de-airing prior to separation from cardiopulmonary bypass, identify new and residual problems prior to removal of cardiopulmonary bypass cannulae to allow for immediate surgical revision, and evaluate ventricular filling and function to help guide fluid and inotropic support [7]. Herein, we provide a review of available technology, probe selection and placement, and care of equipment utilized for TEE in congenital heart surgery. Pearls and pitfalls related to hemodynamic monitoring and anatomical variants are also discussed.

1.1. Preoperative considerations

After the induction of anesthesia and placement of invasive monitoring, a complete TEE examination begins. Some centers will begin the imaging while the circulating nurse preps and drapes the patient for surgery, others wait until the sterile draping is complete and the surgical field isolated by a vertical barrier to minimize the risk of inadvertent contamination of the operative site. In either scenario, the cardiologist and sonographer must be aware of the surgical field and the need for maintaining its sterility at all times. The initial TEE study is performed to confirm the preoperative diagnosis, look for additional information that might have been missed on the transthoracic echocardiogram, and serve as a baseline for comparison with the post-repair study.

1.2. Probe selection

There are a number of proprietary TEE probes and imaging software platforms available. Today, even the smallest probes have multiplane technology with the capability to obtain a 360-degree continuum of two-dimensional tomographic images of the heart and perform complete Doppler studies (color flow, pulse and continuous) as well as M-mode [8]. Phillips, Siemens, GE, and Hitachi currently are the most commonly used systems in pediatrics with Phillips and GE manufacturing the only probes small enough for children weighing 2.5 kg.

Selection of the proper probe depends on the size of the patient and the maximum diameter of the ultrasound transducer at the tip of the probe (Table 1). Selecting a probe that is too large can injur the esophagus while selecting a probe that is too small will result in poor image quality from either a lower density of piezoelectric crystals

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Table 1
Characteristics of commonly used transesophageal echocardiography (TEE) transducers.

	Model[a]	Mode	Min weight (Kg)[b]	TEE tip (width x height x length (mm))	Shaft (diameter mm x length cm)	Frequency (MHz)	Piezoelectric crystals (elements)
Phillips	X7-2t	3D xMatrix	30	16 × 12 × 40	10 mm × 106 cm	7-2	> 2500
	S7-2	Omni III	25	14.9 × 12.5 × 35	10 mm × 90 cm	7-4	64
	S7-3t	Mini Multiplane	3–3.5	10.7 × 8 × 27	7.4 mm × 70 cm	7-3	48
	S8-3t	Micro TEE	2.5	7.5 × 5.5 × 18.5	5.2 mm × 88 cm	8-3	32
GE	6Tc/6Tc-RS	Vivid Adult multiplane	25	14 × 12 × 45	10.5 mm × 110 cm	8-2.9	64
	9T/9Tc-RS	Vivid Pediatric multiplane	3–3.5	10.9 × 8.4 × 35.2	7 mm × 70 cm	10-3	48
	10T-D	Vivid Neonatal	2.5	7.6 × 5.6 × 16		10 – 3.3	
Siemens	V5M	Acuson (multiplane)	25	14.5 × 11.5	10.5 mm × 110 cm	7-3	64
	V7M	Acuson (mini-multiplane)	3–3.5	10.9 × 8	7 mm × 70 cm	8-4	48
Hitachi	MXT1	Adult 3D TEE	30	16.6 × 13.3 × 41	10 mm × 103 cm	10-1	> 2000
	S3ESEL	Adult Multiplane	25	14.6 × 11.8 × 24	9 mm × 100 cm	8-2	64
	S3ESCLS	Pediatric Multiplane	3–3.5	10.7 × 8.1 × 26	7.2 mm × 70 cm	8-2	48

[a] Models' specifications obtained from manufacturer website and/or email communication with correspondent representative.
[b] Minimum weight per manufacturer or derived from previous studies on similar transducer dimensions [6–8,19,20].

(elements) and/or reduced contact with the esophagus.

Real-time three-dimensional TEE, which is the newest technology available, is not yet possible in children under 30 kg. Three-dimensional imaging is of particular value during surgical valve repair and will become feasible in smaller patients as miniaturized technology progresses [9]. Each TEE probe has suggested manufacturer patient minimum weight guidelines although there are reports in the literature of safe use below these weight recommendations [6,10]. An important point for clinicians, TEE probes from one company and imaging platforms from another are not compatible and even within the same company imaging platforms/machines are not interchangeable.

TEE probe selection is made on a case by case basis. Most congenital heart programs will have a selection of probes ranging in size from a micro-multiplane probe with a 7.5 mm maximum tip diameter with 32 elements, a mini-multiplane with a 10.7 mm tip and 48 elements, an adult multiplane (omniplane) with a 14–14.9 mm probe tip containing 64 elements, and finally, a three-dimensional probe with a 17 mm tip and 2400 elements. Imaging frequencies range from 4.0 to 8.0 MHz. Catheter-based single-plane ultrasound probes (ICE) developed for navigation inside blood vessels can be placed in the esophagus of neonates between 1 and 2 kg and provide valuable echocardiographic information although limited to the longitudinal plane [11]. Alternatively, epicardial echocardiography may be used with very small infants and is the preferred approach in many centers for neonatal congenital heart surgery.

1.3. Probe placement and potential complications

A TEE probe is an expensive and delicate piece of equipment. It must be cleaned properly, maintained and inspected regularly, and undergo an electrical leakage test prior to each use. The probe should be in the operating room arena and ready prior to the induction of anesthesia. During the procedure, the probe needs to be handled carefully, paying particular attention to protect the tip containing the piezoelectric crystals. After induction of anesthesia, endotracheal intubation, the insertion of invasive monitors (arterial and central venous catheters), and aspiration of gastric contents, the probe is inserted through the mouth keeping in mind that even a securely taped endotracheal tube can become dislodged. In most centers, the anesthesiologist places and removes the TEE probe to mitigate the risk of a life-threatening accidental extubation.

The TEE echocardiography probe needs to be well-lubricated with water-soluble gel prior to insertion into the mouth. A slight anteflexion of the tip is often useful when advancing the probe around the tongue into the posterior pharynx. The tip should then be straightened as the probe is advanced into the esophagus. If resistance is encountered once past the tongue, the probe should not be advanced. Instead, additional techniques such as forward displacement of the mandible, using a gloved finger to guide the probe, temporarily deflating the endotracheal tube cuff, and direct visualization of the oropharynx with a laryngoscope should be employed. In children < 10 kg, turning the head to one side may allow the probe to pass more readily by dilating the contralateral pyriform sinus [12]. While serious complications related to TEE are rare, the list includes pharyngeal, esophageal and gastric perforation, mucosal lacerations causing severe bleeding, and accidental extubation [13,14]. Crepitus in the neck or upper thorax, pneumomediastinum, retropharyngeal gas on radiography, mediastinitis, and sepsis may be signs of perforation. Non-major complications include dental and lip injuries, dysphagia, hoarseness, and mild pharyngeal, esophageal and gastric mucosal bleeding [15,16]. Current recommendations for the prevention of subacute endocarditis exclude TEE echocardiography as an indication for prophylactic antibiotic use [17].

Following insertion, a soft gauze bite block between the patient's molars can prevent probe damage from sharp incisors in patients with teeth. Paralysis and the inability of the patient to bite does not prevent the probe from scraping across the incisors during manipulation of the probe for image acquisition, and the use of bite blocks is recommended [18]. Two probe sizes should be available when a patient is at or slightly below the manufacturer recommended weight limit. If the larger probe can be placed with minimal resistance, the images will be better, the challenge is careful insertion of the relatively inflexible tip. Each time the micro-multiplane probe is used, a discussion amongst the surgeon, cardiologist, sonographer and anesthesiologist should occur before the surgical time-out and additional equipment made ready and available if indicated. The image quality of the micro-multiplane can be suboptimal and the surgeon may prefer holding a sterilely sheathed epicardial probe to assess the repair.

Hemodynamics and respiratory parameters need to be closely monitored. The anesthesiologist must be vigilant and monitor the arterial blood pressure, end-tidal carbon dioxide, peak airway pressure and oxygen saturation while the cardiologist and sonographer are obtaining images. Hypotension from aortic and/or left atrial compression, vagally mediated bradycardia, and impaired ventilation from tracheal compression or movement of the endotracheal tube into the right mainstem bronchus are common in small children and the probe may need to be repositioned or removed completely. In a study by Randolph et al., 12% of patients under 4 kg experienced hemodynamic or respiratory compromise [2].

1.4. Special anatomic considerations

Occasionally, an arterial line will be placed in a limb supplied by an undiagnosed aberrant subclavian artery and the arterial tracing lost after insertion of the TEE probe. In this situation, the probe should be removed, and the arterial line moved to another extremity before proceeding further.

Severe hemodynamic instability may occur in patients with total anomalous pulmonary venous return after probe placement due to compression of the pulmonary venous confluence. The TEE probe will need to be withdrawn and repositioned after the sternotomy and potentially after initiation of cardiopulmonary bypass.

1.5. Probe removal and care

After the findings of the post-repair examination have been reviewed and discussed, the surgical team should be part of the decision-making process regarding the timing of probe removal. The surgical team may want additional information regarding function and filling while achieving hemostasis. When the surgical and anesthesiology team agree no further information will be needed, the probe is removed. The anesthesiologist carefully removes the probe while holding the endotracheal tube to minimize the risk of dislodgement. In a small infant, the endotracheal tube can be pulled out from the trachea by the forward movement of the TEE probe without any apparent movement of the tube externally. The end-tidal carbon dioxide trace needs to be assessed vigilantly during probe removal to recognize unplanned extubation.

Each institution has their own policy for the transportation, cleaning and disinfection of TEE probes. There are no nationally standardized guidelines. Most congenital heart centers wipe the probe immediately with an enzymatic sponge to remove gross contaminants before transportation in a puncture proof container to the area where sterile processing will occur. The next step involves testing for electrical safety before proceeding to high-level disinfection. High-level disinfection kills microorganisms but not spores. When the disinfection cycle is complete, the probe is placed in a drying/storage cabinet with the tip protected. The probe needs to be tagged with the date processed, the expiration date (usually 14 days), the leak test results and the staff member's name responsible for the processing. It is very important that probe is handled with care at each stage of the cleaning process as repairs are costly.

2. Absolute and relative contraindications to TEE echocardiography

An unrepaired tracheoesophageal fistula is an absolute contraindication to TEE [7]. Previous esophageal surgery may be a relative or absolute contraindication depending on the degree of esophageal narrowing. Consultation with an experienced gastroenterologist and development of a plan to perform upper endoscopy with possible dilatation prior to probe placement is prudent. A severe stricture not amenable to dilatation will prevent safe probe placement. TEE is not needed for repair of a complete vascular ring; its use may lead to complete tracheal compression and severe respiratory compromise and should be avoided. Most congenital heart centers defer transgastric imaging in patients presenting for open-heart surgery with a gastrostomy tube/button with or without a Nissen fundoplication to avoid injury at the site of the gastrostomy tube, gastrostomy tube dislodgement, or esophageal trauma. A severe coagulopathy, recent gastroesophageal bleed/esophagitis/gastric ulcer, history of esophageal varices or diverticulum, pathology of the oropharynx, cervical spine instability/abnormalities are relative contraindications but can be managed proactively with a thoughtful multidisciplinary approach.

3. Conclusion

TEE is an important adjunct to congenital heart surgery, and minimizing the risks involved with the TEE component of the case should be a goal for every surgical team.

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Declaration of competing interest

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