Endoscopic Evaluation of the Esophagus in Infants and Children Immediately Following Intraoperative Use of Transesophageal Echocardiography*

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Objective: Intraoperative transesophageal echocardiography (TEE) has evolved as an essential technique for use during pediatric cardiac surgery; however, few studies have evaluated the safety of TEE in children. This series reports endoscopic examination of the esophagus following intraoperative TEE in pediatric patients.

Methods: Fifty children undergoing congenital heart surgery underwent flexible esophagoscopy that was performed after completion of their heart surgery and after the removal of the transesophageal echo probe. The patients’ ages ranged from 4 days to 10 years old, and their weight ranged from 3.0 to 39.8 kg, with a mean weight of 12.6 kg.

Results: Thirty-two of 50 patients (64%) had abnormal results shown on esophageal examinations; this occurred more frequently in the subset of patients weighing < 9 kg. No long-term feeding or swallowing difficulties were noted in any of the 48 patients who survived.

Conclusions: Intraoperative TEE in infants and children frequently caused mild mucosal injury. Care must be exercised in the insertion and manipulation of the probes.

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Key words: cardiovascular; echocardiography; esophagus

Abbreviations: TEE = transesophageal echocardiography

Transesophageal echocardiography (TEE) has evolved as an indispensable method to assess cardiac structure and function in infants and children with congenital heart disease. In medical centers where complex heart surgery is performed in neonates and infants, TEE is utilized intraoperatively to define anatomy, evaluate postoperative function, and assess any residual defects after repair procedures. With the development of smaller transesophageal probes, TEE has routinely been used in neonates weighing as little as 3.0 kg.

Concerns over the safety of intraoperative TEE, particularly in smaller infants and neonates, prompted this study, specifically to directly inspect the esophagus immediately following intraoperative TEE in pediatric patients undergoing cardiac repairs with cardiopulmonary bypass.

Materials and Methods

Patient Population

Fifty children were enrolled in this study over a 12-month period, after informed parental consent was obtained. There were 27 boys and 23 girls ranging in age from 4 days to 10 years old; 19 of the patients were < 1 year old, and their weight ranged from 3.0 to 39.8 kg (mean, 12.6 kg).

The congenital defects repaired are outlined in Table 1. Cardiopulmonary bypass times ranged from 18 to 230 min. In 28 patients, aortic cross-clamping was necessary for periods of 19 to 92 min. Deep hypothermic circulatory arrest was used in seven patients.

Procedure

Pediatric TEE probes (models 21365A or 211366A; Hewlett-Packard; Andover, MA) were inserted by anesthesiologists after
the patient was intubated orotracheally. The TEE probe tips were lubricated and introduced with the transducer facing anteriorly; direct laryngoscopy was used if any resistance was met. The TEE probe then was used to examine the patient’s cardiac chambers, valves, septum, and contractile function. With the initiation of cardiopulmonary bypass, the probe was turned off and left in place in the esophagus. The deflection controls of the TEE probe were left in the unlocked position. The patients were actively cooled on cardiopulmonary bypass, with the lowest temperatures ranging from 17°C to 34°C (mean, 25.1°C). Following intracardiac repair, the TEE probe was again used to evaluate cardiac function and to assess whether the repair was satisfactory. The TEE probes were removed after protamine was administered. The TEE probes remained in the esophagus an average of 248 min (range, 120 to 420 min), and were “on” for an average of 161 min (range, 80 to 280 min).

At the conclusion of the heart surgery, flexible upper GI endoscopy was performed by a pediatric surgeon and the endoscopy images were videotaped for review. The patient’s esophagus was examined down into the stomach, with attention directed to identifying any areas of erythema, edema, erosion, hematoma, or mucosal changes. When present, abnormalities were assessed for their location in the esophagus, the extent of injury in centimeters, and the percentage of esophageal circumference involved. All children were monitored postoperatively for feeding and swallowing difficulties, GI bleeding, and emesis.

**RESULTS**

Abnormal results of an esophageal examination were noted in 32 of 50 patients (64%; Table 2).

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>No. of Patients</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Erythema</td>
<td>27</td>
<td>54%</td>
</tr>
<tr>
<td>Edema</td>
<td>12</td>
<td>24%</td>
</tr>
<tr>
<td>Hematoma</td>
<td>11</td>
<td>22%</td>
</tr>
<tr>
<td>Mucosal erosion</td>
<td>7</td>
<td>14%</td>
</tr>
<tr>
<td>Petechiae</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

Comparing the smallest 25 patients (weight, 3.0 to 8.9 kg) with the largest 25 patients (weight, 9.0 to 39.8 kg) demonstrated a significant difference in the probability of an abnormal result of the esophageal examination (p < 0.05; Table 3). Twenty of 25 smaller patients (80%) had abnormal examination results, compared to 12 of 25 (48%) of the larger patients. If one considers hematoma, mucosal erosion, and petechiae to suggest esophageal injury, these findings also occurred more commonly in the smaller patients (44% vs 24%).

Forty-eight patients were discharged from the hospital. One patient died 4 days postoperatively from neurologic complications after repair of total anomalous pulmonary venous return. The other death occurred 2 months after a stage I Norwood operation and was caused by peritonitis and sepsis from necrotizing enterocolitis.

Of the 48 survivors, 3 had emesis within the first 48 h after surgery. All three were able to eat by the third postoperative day without any subsequent difficulties. Long-term feeding difficulties were encountered in only two patients, both of whom had neurologic dysfunction (due to hydrocephaly in one patient and Down’s syndrome in the other). Both patients required long-term enteral tube feedings. No feeding difficulties attributable to TEE usage were noted.

**DISCUSSION**

TEE has been used clinically for >20 years, initially for motion-mode imaging of the heart, and followed by two-dimensional TEE, which was introduced in 1981.1 Over the last 10 years, TEE has been used increasingly, as refinements in design and engineering have permitted the development of
smaller scopes and transducers capable of high resolution in multiple planes.

The inflexibility of the transducer tip has limited the use of adult-size scopes in children; however, pediatric biplane scopes are now available with distal tip dimensions of 9.1 mm wide, 8.8 mm thick and 27 mm long (model 21366A Biplane, PTEE 7.5/5.5 MHz Phased-Array, 64 element transducer; Hewlett-Packard). The rapid development of these miniature probes has led to their widespread clinical use both in and out of the operating room, but few studies have addressed the inherent risks associated with the use of TEE probes in pediatric patients. A multicenter survey of 10,419 TEE studies in adults showed that there were pulmonary, cardiac, or bleeding complications in 0.18% of patients.

The theoretical risks of intraoperative TEE can be roughly categorized in four categories:

1. Injury during scope insertion or during manipulation of the control knobs.
2. Thermal mucosal injury from probe heat.
3. Mucosal pressure necrosis from a large probe or prolonged scope flexion.
4. Compression of adjacent structures, such as the bronchus, aorta, or atrium.

Injury by Scope Insertion: Injuries to the esophagus during insertion are most likely to occur at the level of the cricopharyngeal muscle. With careful technique and selection of the appropriate probe size, most patients’ anatomy can easily allow the passage of a TEE probe. Exceptions may occur in patients with intrinsic esophageal abnormalities or lesions such as congenital trancesophageal fistula or esophageal diverticuli. Children with Down’s syndrome may have intrinsic narrowing of their hypo-pharyngeal structures, making the passage of the TEE probe difficult or impossible.

Thermal Injury: Ultrasound transducers are inefficient at converting electrical power to acoustic power; therefore, approximately 75% of the power is dissipated as heat through the transducer. The risk of thermal injury to the esophageal mucosa led to the incorporation of a thermistor into the probe tip to constantly monitor the probe temperature. The transducer will automatically shut off if the probe surface temperature exceeds a preset level, theoretically ensuring that the patient does not receive thermal burns.

O’Shea and coworkers manipulated TEE probes in four monkeys (mean weight, 5.7 ± 0.6 kg) and eight mongrel dogs (mean weight, 29.8 ± 1.4 kg) for up to 8.5 h and failed to find any histologic evidence of thermal injury to the sectioned esophagi. It is not clear from their study how long the probes were in contact with a single area of the esophagus, or whether enough heat was generated to cause an automatic shutdown of the transducer power. It would seem prudent to leave probes on for the minimal time needed to perform the intraoperative assessment, and, certainly, to leave them off during the induced hypothermia portion of the surgery, when local warming of the mediastinum and heart could be deleterious.

Pressure Necrosis: Another potential source of esophageal injury with TEE is pressure necrosis. Describing a technique to measure contact pressure between the TEE probe and the esophageal wall, Urbanowicz and coworkers were able to develop pressure up to 60 mm Hg in one patient. Their study suggests that dangerous levels of pressure on the esophageal wall can occur with scope flexion. This pressure may be the cause of intramural hematomas or mucosal tears complicating TEE in heparinized patients.

Compression: A risk of intraoperative TEE that deserves mention is the compression of adjacent structures, such as the trachea, bronchus, descending aorta, or atrium. Although this was not observed in the 50 pediatric patients in this study, we have anecdotally noted signs of compression in 2 neonatal patients, 1 with total anomalous pulmonary venous return and 1 with tetralogy of Fallot with absent pulmonary valve. Both of these patients weighed between 2.6 kg and 3.0 kg, and both developed hypotension and signs of airway obstruction after the TEE probe insertion. All signs of compression resolved after probe removal. Others have noted arrhythmias and pulmonary symptoms during TEE studies in adults, which also might be related to compression of mediastinal structures. It would seem prudent to remove the probe in any child who suddenly develops hemodynamic instability or breathing difficulty after TEE probe placement.

This study demonstrates that intraoperative TEE in infants and children frequently causes mild mucosal injury, particularly in infants and neonates weighing as little as 3 kg. Esophageal injury may result from a combination of factors that include forceful insertion, excessive scope manipulation, extreme flexion of the scope tip, or transducer heat transfer.

Although intraoperative TEE can be safely performed even in very small infants, meticulous care must be exercised in the insertion and manipulation of these probes.
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REFERENCES