6-1-2010

Initial experience with a miniaturized multiplane transesophageal probe in small infants undergoing cardiac operations.

Sinai C. Zyblewski

Girish S. Shirali
Children's Mercy Hospital

Geoffrey A. Forbus

Tain-Yen Hsia

Scott M. Bradley

See next page for additional authors

Recommended Citation

Zyblewski, S. C., Shirali, G. S., Forbus, G. A., Hsia, T., Bradley, S. M., Atz, A. M., Cohen, M. S., Graham, E. M. Initial experience with a miniaturized multiplane transesophageal probe in small infants undergoing cardiac operations. *The Annals of thoracic surgery* 89, 1990-1994 (2010).

Creator(s)

Sinai C. Zyblewski, Girish S. Shirali, Geoffrey A. Forbus, Tain-Yen Hsia, Scott M. Bradley, Andrew M. Atz, Meryl S. Cohen, and Eric M. Graham

HHS Public Access
Author manuscript
Ann Thorac Surg. Author manuscript; available in PMC 2015 March 11.

Published in final edited form as:
Ann Thorac Surg. 2010 June ; 89(6): 1990–1994. doi:10.1016/j.athoracsur.2010.01.088.

Initial Experience With a Miniaturized Multiplane Transesophageal Probe in Small Infants Undergoing Cardiac Operations

Sinai C. Zyblewski, MD, **Girish S. Shirali, MBBS**, **Geoffrey A. Forbus, MD**, **Tain-Yen Hsia, MD**, **Scott M. Bradley, MD**, **Andrew M. Atz, MD**, **Meryl S. Cohen, MD**, and **Eric M. Graham, MD**
Divisions of Pediatric Cardiology and Cardiothoracic Surgery, Medical University of South Carolina, Charleston, South Carolina, and Division of Pediatric Cardiology, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

Abstract

Purpose—There has been reluctance to use intraoperative transesophageal echocardiography (TEE) in small infants. We assessed the utility and safety of a new miniaturized multiplane micro-TEE probe in small infants undergoing cardiac operations.

Description—Hemodynamic and ventilation variables were prospectively recorded before and after micro-TEE insertion and removal in infants weighing 5 kg or less undergoing cardiac operations.

Evaluation—The study included 42 patients with a mean weight of 3.6 ± 0.9 kg (range, 1.7 to 5 kg). All probe insertions were successful. There were no complications or clinically significant changes in hemodynamic or ventilation variables. Information provided by TEE resulted in surgical revision in 6 of the 42 patients.

Conclusions—The micro-TEE provides high quality, useful diagnostic images without hemodynamic or ventilation compromise in small infants undergoing cardiac operations. This advance is important with the growing trend towards complete repair of complex structural heart disease in small infants.

Intraoperative transesophageal echocardiography (TEE) has been demonstrated to have a major effect in pediatric cardiac operations [1]. Increased morbidity, mortality, and costs [2, 3] can be expected when a patient leaves the operating room with significant residual

Address correspondence to Dr Graham, Division of Pediatric Cardiology, Medical University of South Carolina, 165 Ashley Ave, MSC 915, Charleston, SC 29425; grahamem@musc.edu.

Dr Shirali discloses a financial relationship with Philips Medical Systems.

Disclosures and Freedom of Investigation
The authors of this article had full control of the design of the study, methods used, outcome measurements, analysis of data, and production of the written report.

Disclaimer
The Society of Thoracic Surgeons, the Southern Thoracic Surgical Association, and *The Annals of Thoracic Surgery* neither endorse nor discourage the use of the new technology described in this article.

defects. Although the overall incidence of complications for TEE is low, TEE has some disadvantages that have limited its use. Reported complications include failure to successfully insert the probe, aortic and airway compression resulting in hemodynamic or ventilatory compromise, inadvertent tracheal extubation, and esophageal or gastric trauma, including perforation. These complications and failures have been reported predominantly in smaller patients [1, 4].

Technology

The miniaturized multiplane micro-TEE probe (Philips Medical Systems, Andover, MA) has a shaft width of 5.2 mm, a transducer tip width of 7.5 mm, and a height of 5.5 mm (Fig 1). In comparison, the commonly used mini-multitransducer has dimensions of 7.5, 10.6, and 8 mm, respectively. The micro-TEE transducer is a 32-element phased array that is equipped with 2 dimensional, color, pulse wave, high pulse repetition frequency, continuous-wave Doppler, M-mode, and color flow M-mode. It has a center frequency of 6 MHz (range. 3.2 MHz to 7.4 MHz). There is a 180° manual image plane control with angular display, anterior and posterior articulation, and an articulation brake. The transducer has tip temperature sensing and display for added safety.

Technique

Patients

Infants weighing 5 kg or less undergoing cardiac operations with intraoperative TEE examination at the Medical University of South Carolina were prospectively enrolled after Institutional Review Board approval and guidelines were met. The clinical indication for TEE was at the discretion of the cardiothoracic surgeon and cardiologist. Exclusion criteria were standard contraindications to TEE, including esophageal obstruction and tracheo-esophageal fistula.

Study Design

Patient demographics and anthropometric measurements were recorded. After the induction of general anesthesia, hemodynamic and ventilatory measurements were recorded. Hemodynamic measurements included heart rate, systolic, diastolic, and mean systemic arterial blood pressure. Ventilatory measurements included peak inspiratory pressure, corresponding tidal volume, and end tidal carbon dioxide.

Only experienced senior echocardiography fellows or attending echocardiographers performed probe insertion, manipulation, and withdrawal. Insertion depth was determined according to visualization of intracardiac structures. During the probe insertion, the patient was closely monitored for hemodynamic and ventilatory complications by the anesthesiologist. The hemodynamic and ventilatory measurements were repeated after probe insertion and then continuously monitored by the anesthesiologist and pediatric cardiologist during the entire course of the TEE evaluation. Blood pressure was monitored continuously by a femoral or umbilical arterial catheter. Cerebral near-infrared spectroscopy was monitored in all patients as a surrogate for cerebral perfusion because TEE compression of head and neck vessels has been reported.

After final TEE assessment of the surgical repair had been completed, all hemodynamic and ventilatory measurements were repeated before and after micro-TEE removal. A clinically significant change was defined as a 20% difference between the measurement before and after TEE insertion or a disruption in hemodynamics or ventilation necessitating premature removal of the TEE probe.

Statistical analysis was performed using a paired two-tailed *t* test to compare the two sets of measurements: before and after micro-TEE probe insertion and before and after micro-TEE probe removal. A value of $p \leq 0.05$ was considered significant. A power analysis (PS 3.0.5 software, Vanderbilt University, Nashville, TN) at a power of 0.80 and an α level of 0.05 was performed for each variable to determine the likelihood of detecting a 20% difference between the before and after measurements. The diagnostic accuracy of the study was confirmed by the surgical report or a postoperative transthoracic echocardiogram in the cardiac intensive care unit.

Clinical Experience

The study enrolled 42 patients, of whom 16 weighed 3.5 kg or less. The mean weight was 3.6 ± 0.9 kg (range, 1.7 to 5 kg) and the mean age was 1.9 ± 1.5 months (range, 0.2 to 4.7 months). All micro-TEE insertions were successful. The micro-TEE probe provided excellent quality diagnostic and Doppler images for all 42 patients studied (Figs 2, 3, and 4). None of the micro-TEE probes had to be prematurely terminated. There were no complications or clinically significant changes in hemodynamic or ventilatory variables in the group as a whole or in any individual patient that could be attributed to the micro-TEE. Continuous monitoring of hemodynamic and ventilatory variables by anesthesia and pediatric cardiology during the entire course of the TEE demonstrated that manipulations of the probe, including insertion, flexion, transgastric imaging, and removal were well tolerated. Minor changes to the ventilator settings were required in a patient who weighed 1.7 kg.

The intraoperative TEE findings resulted in surgical revisions in 6 patients, 3 of whom weighed 3.5 kg or less. The indications for surgical revision determined by the intraoperative TEE included common atrioventricular valve replacement, mitral valve repair, tricuspid valve repair, pulmonary artery band adjustment (2 patients), and coronary fistula ligation.

All studies performed with the micro-TEE probe were of sufficient quality to adequately evaluate the cardiac operation. No diagnostic discrepancies were found by surgical report or by postoperative transthoracic imaging in the intensive care unit.

Comment

With the advances in cardiac surgical techniques, anesthesia, and perioperative care, complete repair of complex structural heart disease in early infancy has become increasingly more successful and popular, thus necessitating a safe and effective imaging technique for small infants [5]. Past efforts to advance intraoperative imaging in small infants have been limited by the large size of available probes. Current manufacturer guidelines recommend 3.5 kg as the lower weight limit for the pediatric multiplane TEE probe. Although the overall incidence of complications is low, several surgical centers describe difficulties with standard biplane or pediatric multiplane TEE probes in their small patients (≤4 kg), such as inability to pass the probe, airway compression, or hemodynamic disturbances [1, 4, 6].

Andropoulos and colleagues [7] demonstrated the safety of TEE in 23 infants who weighed between 2 and 5 kg; however, the experience was limited to biplane imaging. Bruce and colleagues [6] described the use of a miniaturized ultrasound transducer-tipped catheter, originally designed for intracardiac use, as an alternative to TEE for very small infants. This catheter was placed successfully in 22 patients, and there were no cases of hemodynamic compromise or airway resistance. Unfortunately, the diagnostic potential and safety of this technique is constrained by its single (longitudinal) plane imaging and lack of tip temperature sensing. More recently, Scohy and colleagues [8] described the safety and utility of the Oldelft (Oldelft Corp, Delft, The Netherlands) micro-multiplane TEE probe in neonates, but infants weighing 2.5 kg or less were not included.

Patients who leave the operating room with significant residual defects have increased morbidity and mortality [9]. Intraoperative TEE has been found to be cost-effective, with a greater effect on younger patients [1, 2]. In a recent study of more than 50,600 postnatal echocardiograms, Benavidez and colleagues [10] identified patient weight of less than 5 kg as an independent predictor of diagnostic errors in echocardiography. These observations highlight the importance of high-quality intraoperative TEE in infants for confirmation of the preoperative diagnosis and evaluation of the surgical repair. Despite these well-described advantages and benefits of intraoperative TEE, our smallest surgical patients had been excluded from this imaging modality. Owing to safety concerns and limitations in technology, our institution historically had not routinely performed intraoperative TEE in infants weighing 3.5 kg or less or in patients who did not require cardiopulmonary bypass.

The micro-TEE enabled us to shift our paradigm of intraoperative imaging for the small infant. The small probe size and high-quality images allowed us to extend this important diagnostic tool to even our smallest surgical patients without compromising hemodynamic or ventilation variables. We were able to perform intraoperative studies in 16 patients who would have otherwise not had a TEE at our institution secondary to weight of 3.5 kg or less.

We speculate that this advance may be an early step towards the ability to provide continuous echocardiographic monitoring of images and echo-derived hemodynamic variables in patients who are critically ill and require life support in scenarios that are not restricted to the intraoperative environment.

A limitation to this study is a lack of a comparison study on each patient with a standard biplane or pediatric multiplane TEE to evaluate image quality. Comparison studies were not performed because many infants were well below the manufacturer's lower weight limit of 3.5 kg for the standard TEE probe. In addition, intraoperative exchange of the TEE probe posed increased risk for disruption and unintentional extubation. Despite the lack of TEE comparison, no diagnostic discrepancies were found by surgical report or postoperative transthoracic imaging. Because all of our studies were successful without significant hemodynamic or ventilatory changes, we have yet to determine the lowest weight and size limit for this micro-TEE probe.

In conclusion, we report the use of the multiplane micro-TEE probe in neonates and infants. Our initial experience demonstrates that the micro-TEE probe provides high-quality, useful diagnostic images without hemodynamic or ventilatory compromise in small infants. This advance is especially important with the growing trend towards complete repair of complex structural heart disease in small infants. We anticipate that the micro-TEE probe will play an important role in the continued progress of perioperative care for the small infant undergoing cardiac operations.

Acknowledgments

We thank Karen Chessa and Pam Ruff; Drs. Tony Hlavacek, Amy Svenson, Javier Gonzalez, Brad Friedman, and Mike Walsh; and the Division of Cardiothoracic Anesthesiology for their assistance with this project.

Dr Shirali is a member of the Advisory Board, has received research grants, and is a consultant for Philips Medical Systems. Philips Medical Systems had no role in this study or access to the information obtained.

References

1. Randolph GR, Hagler DJ, Connolly HM, et al. Intraoperative transesophageal echocardiography during surgery for congenital heart defects. J Thorac Cardiovasc Surg. 2002; 124:1176–1182. [PubMed: 12447184]
2. Bettex DA, Pretre R, Jenni R, Schmid ER. Cost-effectiveness of routine intraoperative transesophageal echocardiography in pediatric cardiac surgery: a 10-year experience. Anesth Analg. 2005; 100:1271–1275. [PubMed: 15845668]
3. Ungerleider RM, Kisslo JA, Greeley WJ, et al. Intraoperative echocardiography during congenital heart operations: experience from 1,000 cases. Ann Thorac Surg. 1995; 60:S539–S542. [PubMed: 8604930]
4. Stevenson JG. Incidence of complications in pediatric transesophageal echocardiography: experience in 1650 cases. J Am Soc Echocardiogr. 1999; 12:527–532. [PubMed: 10359925]
5. Hirsch JC, Mosca RS, Bove EL. Complete repair of tetralogy of Fallot in the neonate: results in the modern era. Ann Surg. 2000; 232:508–514. [PubMed: 10998649]
6. Bruce CJ, O'Leary P, Hagler DJ, Seward JB, Cabalka AK. Miniaturized transesophageal echocardiography in new-born infants. J Am Soc Echocardiogr. 2002; 15:791–797. [PubMed: 12174348]
7. Andropoulos DB, Stayer SA, Bent ST, Campos CJ, Fraser CD. The effects of transesophageal echocardiography on hemodynamic variables in small infants undergoing cardiac surgery. J Cardiothorac Vasc Anesth. 2000; 14:133–135. [PubMed: 10794329]
8. Scohy TV, Gommers D, Jan ten Harkel AD, Deryck Y, McGhie J, Bogers AJ. Intraoperative evaluation of micro-multiplane transesophageal echocardiographic probe in surgery for congenital heart disease. Eur J Echocardiogr. 2007; 8:241–246. [PubMed: 17482518]
9. Rosenfeld HM, Gentles TL, Wernovsky G, et al. Utility of intraoperative transesophageal echocardiography in the assessment of residual cardiac defects. Pediatr Cardiol. 1998; 19:346–351. [PubMed: 9636259]
10. Benavidez OJ, Gauvreau K, Jenkins KJ, Geva T. Diagnostic errors in pediatric echocardiography: development of taxonomy and identification of risk factors. Circulation. 2008; 117:2995–3001. [PubMed: 18519849]

Fig 1.
Dimensions of the micro-multiplane transesophageal echocardiography probe.

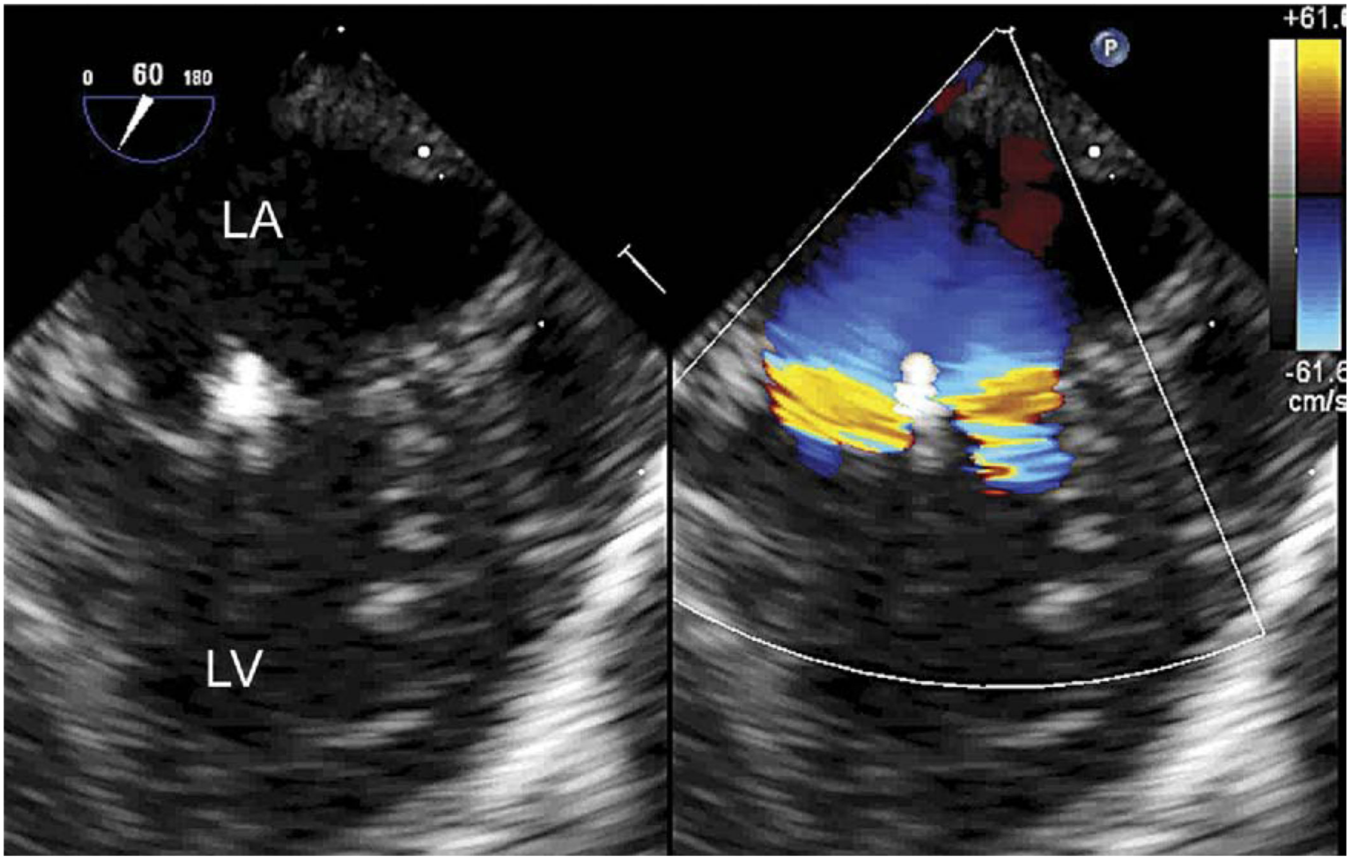

Fig 2.

This image was obtained in a 3-monthold, 5-kg infant with atrioventricular septal defect and severe left-sided atrioventricular valve regurgitation. In addition to closing the cleft, the surgeon created a double-orifice left atrioventricular valve. This 60° image of the surgically created double-orifice mitral valve demonstrates prograde flow thorough both orifices. (LA = left atrium; LV = left ventricle.)

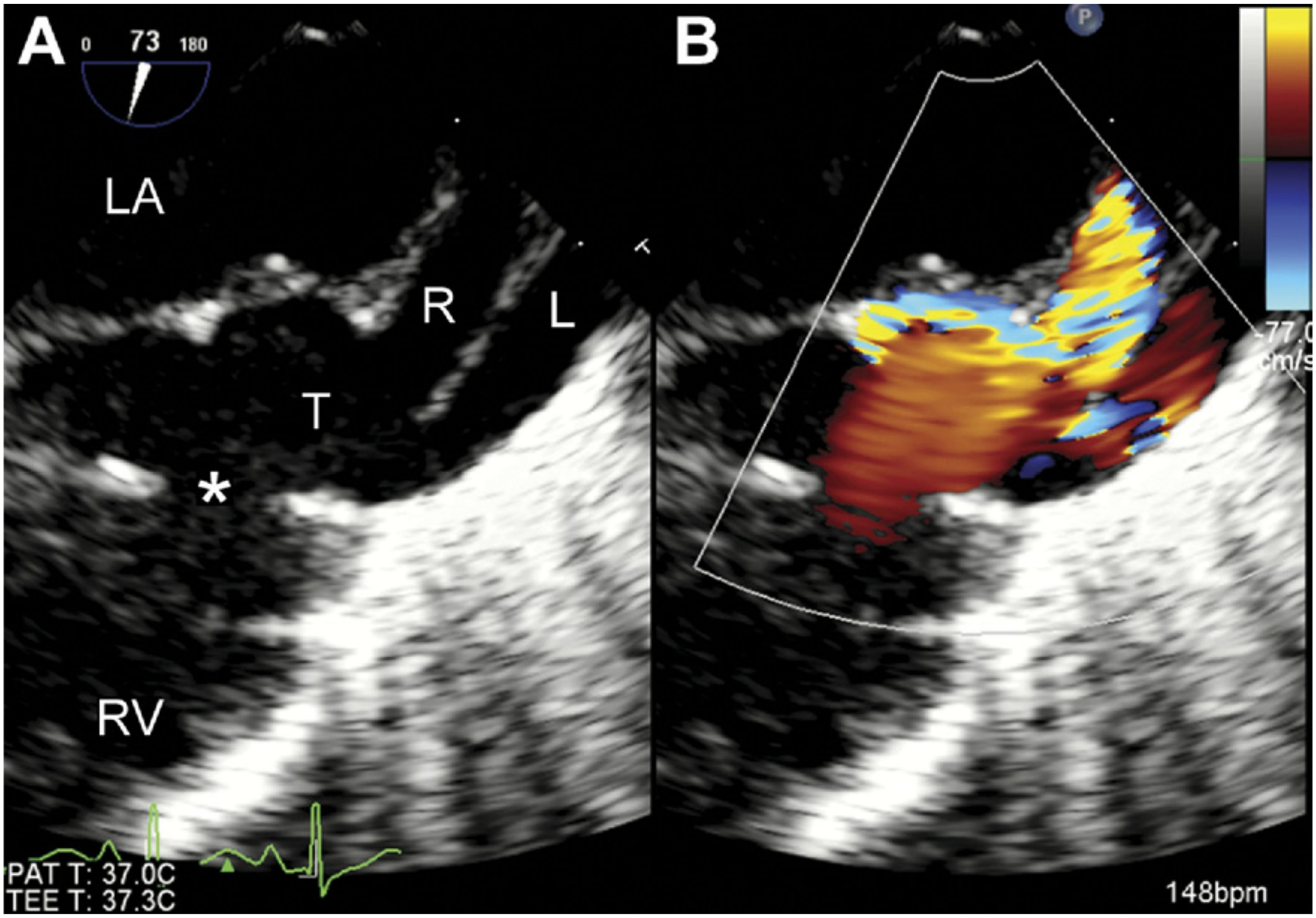

Fig 3.

Simultaneous (A) 2-dimensional and (B) color-flow Doppler images are shown in a 1-week-old, 3.7-kg infant undergoing repair of truncus arteriosus. There is right to left flow across the ventricular septal defect (asterisk). Note the very short-segment of the main pulmonary artery arising from the truncal root (T), before bifurcating into the right (R) and left (L) pulmonary arteries. (LA = left atrium; RV = right ventricle.)

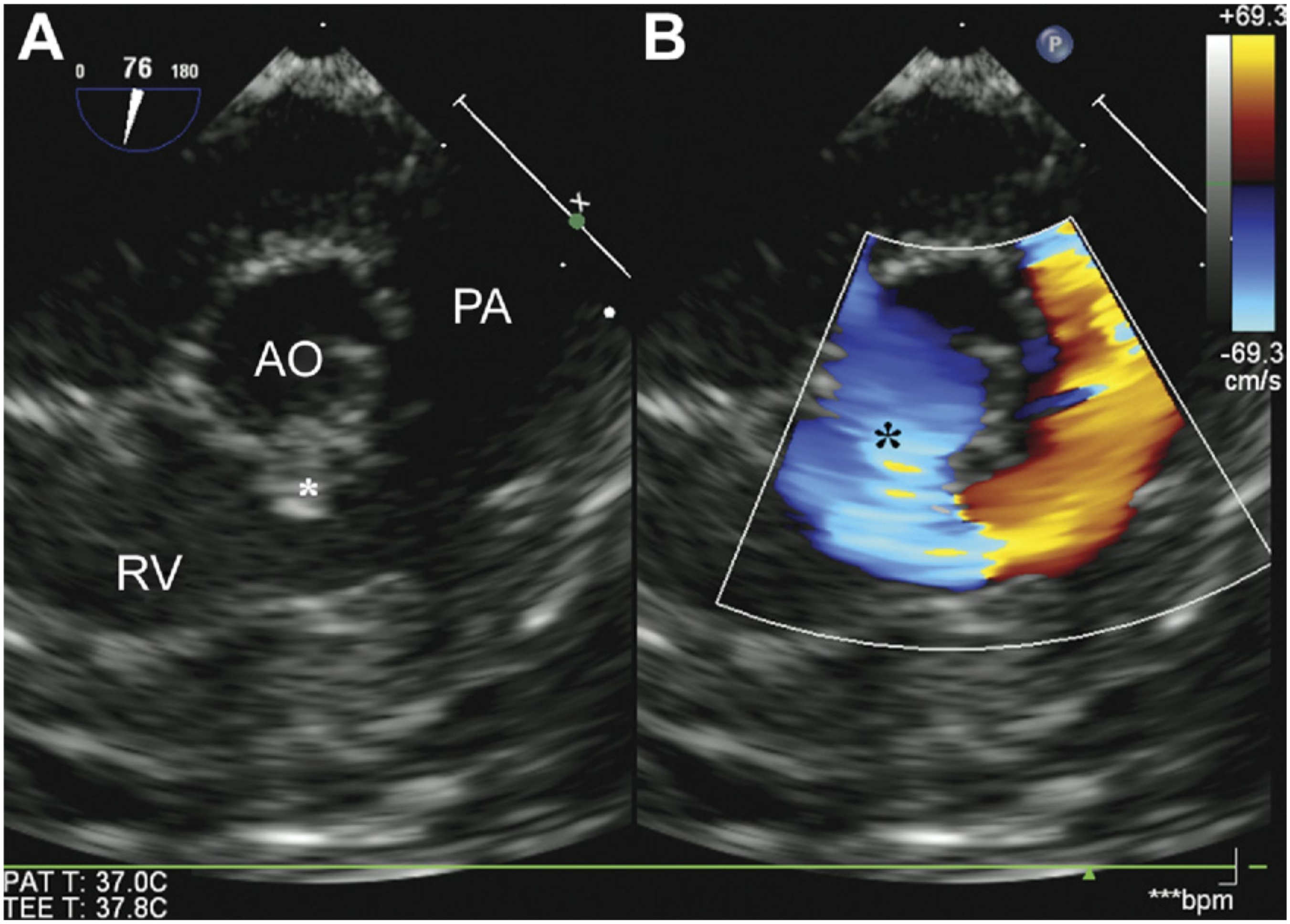

Fig 4.

Simultaneous (A) 2-dimensional and (B) color-flow Doppler images are shown in a 3-week-old, 2.8-kg neonate undergoing repair of a membranous ventricular septal defect. Preoperative transthoracic imaging raised concerns for potential tricuspid valve straddling. Transesophageal imaging demonstrated no chordal tissues crossed the ventricular septum, and a complete repair was performed. Notice the redundant tricuspid valve tissue obscuring the defect on 2-dimensional imaging; however, the defect is clearly seen with color Doppler (black asterisk). There is mild nonobstructive anterior malalignment of the infundibular septum (white asterisk). (AO = aorta; PA = pulmonary artery; RV = right ventricle.)