Incorporation of Basic Transesophageal Echocardiography Training into Anesthesiology Residency

ABSTRACT

The clinical value of perioperative transesophageal echocardiography (PTE) has led to its increasing use for routine monitoring outside the cardiac operating room. Anesthesiologists need formal training in order to demonstrate competency in basic PTE. Therefore, the American Society of Anesthesiologists and Society of Cardiovascular Anesthesiologists have jointly established guidelines for competency and proficiency in basic PTE among anesthesiologists. This provides an ideal opportunity to develop and incorporate a structured basic TEE training program into the anesthesiology residency program that would enhance the likelihood of obtaining formal certification.

Medical simulation is an efficient and effective educational means to acquire knowledge and technical skill. We hypothesize that heuristic use of transesophageal echocardiography (TEE) simulation technology will improve the availability and quality of basic TEE training for anesthesiology residents. Our research addresses this hypothesis through two specific aims. Specific Aim 1: To develop an educational strategy for basic PTE certification incorporating a TEE simulator that develops, maintains, and assesses basic TEE proficiency. This educational strategy will be developed in collaboration with the Departments of Anesthesiology at Duke University and Vanderbilt University. Specific Aim 2: To test the effectiveness of adjuvant simulator training (AST) versus traditional clinical training (TCT) in terms of the development, maintenance, and assessment of basic TEE skills of anesthesiology trainees across two academic institutions. This training program shows promise for application in other anesthesiology residency programs, which will eventually increase the number of anesthesiologists qualified to employ TEE in the perioperative period.
RESUBMISSION STATEMENT

Not Applicable
RESEARCH PLAN

A. Specific Aims:

The goal of this project is to improve competency and proficiency of anesthesiology trainees in basic TEE. Our proposal will measure the impact of TEE simulation technology in formal training programs at Vanderbilt and Duke University. Future research will examine whether basic PTE certification can improve the outcomes of surgical patients.

Hypothesis: Adjuvant simulator training facilitates superior development and maintenance of knowledge and skills compared with traditional clinical training for basic TEE.

Specific Aim 1: To develop a structured basic TEE training program incorporating the use of a TEE simulator.

Specific Aim 2: To determine the effectiveness of adjuvant simulator training versus traditional clinical training in the development, maintenance, and assessment of basic TEE skills.

B. Background and Significance

B.1. The Problem: Standard intraoperative monitors are effective for detection of life-threatening perturbations but often provide little or no information about their mechanisms. Similarly, advanced invasive hemodynamic monitoring with pulmonary artery catheters offers limited benefit in the setting of non-cardiac surgery with a reported complication rate between 5-10% (1,2). TEE is increasingly recognized as an alternative monitor that can also elucidate the mechanism of life threatening hemodynamic perturbations. With the aging of the population and increasing acuity of surgical patients the increased availability of anesthesiologists proficient in enhanced monitoring techniques may lead to improved outcomes for surgical patients.

B.2. TEE for Perioperative Monitoring: A survey of cardiac anesthesiologists formally trained in TEE demonstrated a significantly higher preference for TEE than for the use of a pulmonary artery catheter (3). Although primarily used in cardiac surgery, a review of the emerging literature suggests an increasing role of TEE in non-cardiac surgery (4). For example, perioperative hypoxia or hypotension of unclear etiology is considered a Class I (supported by the most robust evidence) indication, and monitoring for myocardial ischemia is regarded as a Class II (supported by less robust evidence) indication (5). A critical review of the
landmark trials that evaluated the use of TEE and its therapeutic impact in the non-cardiac surgical setting, strongly endorsed anesthesiologists’ familiarity with perioperative TEE monitoring and its use to its fullest potential to achieve better monitoring and improved outcomes (4). The review emphasized the importance of training a greater number of anesthesiologists in TEE. That said, despite the widespread availability of TEE equipment in US hospitals, less than 30% of anesthesiologists are formally trained in the use of perioperative TEE (4).

B.3. The Obligation to Train Effectively: Anesthesiology residency programs have an obligation to provide training in basic TEE so that future anesthesiologists are qualified to use TEE appropriately for intraoperative monitoring. The National Board of Echocardiography (NBE) has introduced a standardized examination and certification process that recognizes the achievement of competence in basic TEE within a defined scope of practice (6). Formal training is required to prepare anesthesiology trainees to obtain certification in basic PTE.

B.4. Overcoming Present Limitations in TEE Training with Medical Simulation: Currently, perioperative TEE education is limited to cardiac operating rooms where the main educators are cardiac anesthesiologists with advanced TEE training and certification. These situations currently restrict residents’ exposure to TEE education and limit opportunities for achieving certification in Basic TEE.

Simulation has emerged as an ideal educational format to supplement clinical experience. As stated by Confucius, “Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand”. Successful skill development demands that a training activity go beyond showing a learner how to do something, but also allows the practice of emerging skills (7). As a form of experiential learning, simulation allows participants to cognitively, affectively and behaviorally processes knowledge, skills, and attitudes in a situation characterized by a high level of active achievement, without the fear of failure. Further, since the delivery of modern healthcare may limit clinical teaching opportunities, patient safety should be enhanced when procedures can be learned and repeated to achieve competence (8,9).

The addition of adjuvant simulator training will expand TEE education for a larger number of trainees independent of the limitations of clinical training opportunities. We propose a structured training program that
will commence during CA1 (PGY2) and continue through CA3 (PGY4) years that will ensure that anesthesia trainees are adept in basic TEE.

B.5. The Simulation Advantage: The relationship between the cardiac anatomy and TEE imaging is complicated by the large number of possible imaging planes and the spatial arrangements of cardiac structures. In the bustle and time-pressure of the clinical setting, TCT can overwhelm the trainee with the rapid introduction to the numerous relationships of imaging planes and cardiac anatomy. A TEE simulator could be used to educate trainees in cardiac anatomy and its relation to TEE imaging without the time pressure and distractions of a clinical environment. TEE simulation is an adjuvant form of training not a replacement for clinical training.

Preliminary Studies:

C.1. Previous Experience: While the elements of a structured training program for TEE have been established, they are limited to physicians in an advanced training program with the objective of achieving competence in advanced TEE for cardiac surgery. The concept and scope of the proposed basic TEE training program are new. Additionally, although some research in TEE simulation has been published, the literature is sparse (10). Our proposal will provide valuable insight into training methods in TEE that can be adopted by other training programs. If our hypothesis is true, TEE simulation sessions can provide a controlled setting in which to develop cognitive and technical skills that can be applied to the dynamic clinical care environment.

Experimental Design and Methods:

Specific Aim 1: To develop a structured basic TEE training program incorporating the use of a TEE simulator.

The proposed training protocol will be divided into three modules:

Module I: Introductory Topics. Didactic introductory topics will cover the principles of ultrasound and knobology, ultrasound artifacts and pitfalls, and a review of the cardiac anatomy. These lectures will precede simulator training and be formatted as web-based presentations to allow ongoing teaching supported by an online forum for questions and answers between residents and instructors. A posttest will assess a resident's knowledge of these topics. Module I will be administered over six weeks, following which residents will proceed
to hands-on sonography training (Module II) with the simulator.

**Module II: Sonography Training.**

**Didactic web-based presentations** covering the basic TEE examination will be available to all residents.

**Small group practical sessions** introducing the ultrasound machines will reinforce the didactic elements from the knobology lecture in Module I.

**Hands-on TEE Training:** In a stepwise fashion, residents will learn how to manipulate the TEE probe to obtain the desired images for a basic TEE examination. This will be accomplished with a combination of AST and TCT; however, for the purpose of this research, one arm of the study will not receive AST during Module II. The TEE simulator used for this study at both sites is commercially available from Heartworks™ (Inventive Medical Ltd, UK).

**Traditional Clinical Training (TCT):** TCT is defined as five TEE examinations performed in the operating room under individual supervision by an anesthesiologist certified in advanced TEE during a six-month period culminating in the completion of a minimum of 32 live TEE exams (more than half of the 50 required for Basic PTE Certification) over the two year training program.

**Adjuvant Simulator Training (AST):** AST is defined as small group TEE simulator workshops (3 residents or less) administered by an anesthesiologist certified in advanced TEE. Residents randomized to receive AST during the appropriate training period will also have access to the simulator for independent practice of basic TEE examination.

**Module III: Clinical Monitoring and Pathology.** In year two, all residents will undertake the clinical monitoring and pathology module. This module will encompass didactic web-based presentations covering hemodynamic calculations, assessment of biventricular function, severe valvular pathology, and “rescue TEE” (which covers identification of life-threatening emergencies e.g. tamponade, aortic dissection etc.). At present, the TEE simulator does not have simulated pathology; however, we will develop workshops to interpose clips of TEE pathology during the course of a simulated examination for the purpose of instruction. Residents will pursue additional TCT in the operating room. Table 1 outlines the workshop topics that will be covered in module III.
Table 1: Workshop topics that will be included in Module III.

At the conclusion of month 24, residents will take a comprehensive multiple-choice examination covering all topics of the training protocol including basic rescue TEE. The cumulative training in this proposed TEE education program is summarized in Table 2, and shows that a significant proportion of the requirements for certification will be achieved.

Specific Aim 2: To determine the effectiveness of adjuvant TEE simulator training versus traditional clinical training in the development, maintenance, and assessment of basic TEE skills.

Study Design: This will be a prospective, randomized cohort study that will cover two consecutive years. Year one enrollees will complete the training program. Year two enrollees (composed of the next class of Clinical Anesthesia Year 1 (CA1) will complete the training program increasing the power of our analysis of year one data by the end of the second year of the study. We will obtain written informed consent from approximately 15 CA1 residents at Vanderbilt and 12 CA1 residents at Duke in year one and a similar enrollment for year two. A multiple-choice examination covering all topics in the basic TEE training program will be administered to all participants. Residents scoring greater than two standard deviations (SD) above the mean will be allowed to
participate in training but their performance will not be included in the experimental analysis. Scoring greater than 2 SD above the mean is indicative of previous training in cardiac imaging. Following the pretest all residents will begin Module I.

**Module 1 Experimental Protocol:** All residents will have access to standardized didactic web-based presentations covering topics such as principles of ultrasound, knobology, ultrasound artifacts, cardiac anatomy, cardiac anatomy in relation to TEE imaging, and overview of a basic 10-view TEE examination. Following six weeks of access to Module I didactic materials, all residents will be assessed with Posttest 1, a multiple-choice examination covering the materials of Module I.

**Block Randomization:** We will implement a block-randomized design at each of the two sites (Vanderbilt University and Duke University) to guarantee that the training arms are comparable. For each cohort (year-one and year-two enrollees), blocks of size four will be identified on the basis of Posttest 1 performance scores, and within each block, two participants will be assigned to training arm A and two to training arm B. The top 4 scores will be assigned to block one, scores 5–8 to block two, scores 9–12 to block three, and scores 13–15 (at VU only) to block four. Because block four comprises three participants, two will be assigned to training arm B and one will be assigned to training arm A. Following block randomization into one of the two training arms, Training Arm A (TRA) or Training Arm B (TRB), all residents will proceed to Module II.

**Module II Experimental Protocol:** TRA and TRB will have equal access to didactic web-based presentations, small group practical sessions, and bi-weekly TEE review conferences but will differ in their methods of hands-on training during the first year of the training program.

- TRA will undergo AST and TCT during Module II.
- TRB will undergo only TCT during Module II.

**Module III Experimental Protocol:** TRA and TRB will have equal access to didactic web-based presentations covering hemodynamic calculations, assessment of biventricular function, severe valvular pathology, and rescue TEE. AST will cover the topics in Table 1.

- TRA will undergo AST and TCT during Module III.
• TRB will undergo AST and TCT during Module III.

Performance Assessments and Data Collection: A standardized metric of TEE performance and knowledge, the Basic Transesophageal Echocardiography Evaluation Tool (BTEET), will measure the trainees’ ability to elucidate standard imaging planes and identify the cardiac anatomy within simulated or live TEE imaging planes. A basic TEE examination is composed of 10 standard imaging planes (or views) that view clinically relevant cardiac anatomy, great vessel anatomy, and cardiac function. The appendix of this application includes directions to view an online video which shows a BTEET assessment of a 10 view simulated TEE exam.

Imaging View [IV] Score: One point will be awarded for obtaining the correct view or imaging plane; therefore, in a 10-view examination, the maximum score possible is 10 points.

Structural Anatomy [SA] % Score (10-View Basic Examination): For each view, the examinee will be asked to identify all visible cardiac structures. The number of correctly identified structures divided by the number of visible structures in each standard view will represent the SA % score for each view. The sum of the SA % scores for each view divided by ten will yield the SA % Score (10-view basic examination).

Duration: The duration needed to perform the ten views of the basic TEE exam will be recorded.

BTEET Administration: The performance on live TEE examinations will be assessed with the BTEET in the operating room by an advanced PTE-certified anesthesiologist. The performance on simulated TEE examinations will be recorded digitally, including audio clips of the resident pointing out cardiac structures, by utilizing the B-Line platform at each institution’s accredited medical simulation facilities. Simulated TEE examinations will be evaluated with the BTEET offline by two advanced PTE-certified anesthesiologists.

BTEET Assessments are defined as three simulated and three live TEE exams that are evaluated independently with the BTEET.

Residents in TRA and TRB will undergo performance assessments according to the following schedule from month zero to month 24 (Figure 1).

• Multiple Choice Examination covering Module I: 6 weeks
• Multiple Choice Examination covering Module I and II: 12 months
• Multiple Choice Examination covering Module I, II, and III: 24 months
• BTEET Assessment: 6, 12, 18, 24 months
• Likert Surveys of Resident Attitude Toward TEE Training: 1, 6, 12, 18, 24 months

Figure 1. The Experimental Training Protocol

10. Primary Outcomes: The primary outcome includes BTEET evaluation of simulated and clinical TEE exams:

1. BTEET IV score: 6, 12, 18, and 24 months
2. BTEET SA% Score (10-view basic examination): 6, 12, 18, and 24 months
3. BTEET Duration: 6, 12, 18, and 24 months

11. Secondary Outcomes: Secondary outcomes will include:

1. Multiple-Choice Examination score covering Modules I and II: 12 months
2. Multiple-Choice Examination score covering Modules I, II, and III: 24 months
3. Likert Surveys of Resident Attitude toward TEE Training: 1, 6, 12, 18, and 24 months
4. Correlation of Simulated and Live BTEET IV scores, SA % (10-view examination), and Duration for validation of the simulator as an assessment tool

12. Statistical Analysis: Because primary outcomes will be collected repeatedly during the follow-up, statistical analyses will use log-linear (i.e., Poisson) mixed effects models for BTEET IV scores, and linear
mixed effects models for BTEET SA % and BTEET duration. We will examine the effect of TRA (versus TRB) over time. Year-one enrollees will be evaluated over the 24-month follow-up period whereas year-two enrollees will contribute to only the analyses at the 6- and 12-month time points. Regression analyses will include adjustment variables: a site indicator (DU vs. VU), a cohort indicator (year-one enrollees vs. year-two enrollees), and Posttest-1 scores.

Analysis of the secondary aims will be based on linear regression for the multiple-choice examination scores, linear mixed effects model regression for the resident attitude survey, and the intra class correlation for simulated and live BTEET score agreement analysis. All regression analyses will compare the training arms and will include as adjustment variables site, cohort, and Posttest-1 scores.

13. Power Analysis: We will report power calculations for the BTEET SA % (10-view examination) analysis. Due to the complexity of the study design, we did not use a “block box” power calculator, but instead used a Monte-Carlo or simulation based approach. This approach involved specifying a reasonable linear mixed effects model, generating data corresponding to the model, conducting the regression analysis using the generated data, and then repeating the process 1000 times. The power we report is the proportion of replications where the treatment effects at 6 months and (separately) at 12 months were statistically significant at the two-sided, 0.05 significance level. For data generation, we set the (residual) error SD and the random intercept SD to be equal to each other. We examined TRA (versus TRB) effect sizes that were equal to the SD, 25% larger than the SD, and 50% larger than the SD. The power to detect these effects were 0.70 when the effect size was equal to the SD, 0.87 when the effect size was 25% larger than the SD, and 0.96 when the effect size was 50% larger than the SD. We believe that effects sizes at least 25% larger than the SD are very likely, and if we are correct, this study has ample power.

14. Expected Outcomes:

**Primary Outcomes:** Demonstration of superior BTEET scores by Training arm A is expected and will validate
our hypothesis. BTEET Image View and Structural Anatomy % (10 View Exam) score are directly proportional to TEE knowledge and skill level while BTEET Duration is inversely proportional to skill level. TRA’s Clinical BTEET Image View and Structural Anatomy % (10 View Exam) scores are expected to be significantly higher at six and twelve months. Conversely TRA’s BTEET Duration is expected to be significantly less at six and twelve months.

**Secondary Outcomes:**

1. **Multiple-Choice Examinations:** We expect that experience with the simulator will lead to TRA scoring higher on Posttest 2.

2. **Likert Surveys:** We expect TRA will report more positive attitudes toward TEE training during Module II.

3. **Correlation of Simulated and Live BTEET** scores is strong evidence that the TEE simulator is a valid assessment tool.

**15. Considerations:** It is anticipated (and our experience) that all residents will grasp the opportunity to gain TEE training. However, some CA-1 residents may decline to participate in this study. Given the simplicity of our study design and the relatively large group of residents we do not anticipate a significant loss of statistical power if some residents decline to participate. Concern is anticipated regarding withholding simulator training from residents in TRB during module II. However, there is presently a knowledge gap regarding the effectiveness of basic TEE training during anesthesiology residency and no evidence of proven benefit of any basic TEE training method—simulated or clinical. Before training programs in basic TEE are incorporated into anesthesiology residency, the effectiveness needs to be demonstrated in order to justify time and resources taken from other areas of anesthesiology training. In addition, we will offer the AST workshops from the second module to the residents in TRB at the start of module III. Thus at the conclusion of two years all residents will have undertaken equivalent training.

A potential source of bias is the experience of residents during individual coaching in the operating room. Written guidelines will be given to all advanced PTE-certified anesthesiologists who will be in a position to
provide individual coaching. Given the dynamic nature of the operating room, standardization of the experience is not possible. Conversely, a benefit of simulator training is the opportunity to learn in a more controlled environment.

16. Summary: This study will be significant in several aspects. First, if our hypothesis is valid, then TEE simulation will be a significant advance in education technology to facilitate the experiential learning of perioperative TEE. This educational method is transferable to other disciplines such as anesthesiology, cardiology, cardiac surgery and critical care to improve proficiency in basic TEE image acquisition and interpretation. Second, the quality of TEE simulators will improve with the introduction of simulated pathology. Our experience of interposing clips of TEE pathology during the course of a simulated TEE exam may help refine future plans that include the development of simulated cardiac pathology such as the topics outlined (Table 1). These modules will facilitate trainee development of the interpretative skills in areas either too complex or infrequent in occurrence to permit enough time for education in the clinical environment. Third, this technology can be used for helping physicians maintain competency in situations where clinical case volume may be insufficient to support current competency requirements.

Finally, funding of this proposal will directly support basic TEE training for approximately 54 anesthesiology residents at two premier academic medical centers. The success of this training program will demonstrate the feasibility of introducing basic TEE training into the anesthesiology residency. Residents will have an excellent education and clinical training experience from which to pursue Basic PTE certification.

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<tr>
<th>Proposed Basic PTE Training Program</th>
<th>Basic PTE Certification</th>
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<td>Minimum 50 Interpreted TEE exams</td>
<td>150 Interpreted TEE exams</td>
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<tr>
<td>Minimum 32 Personally Performed TEE Exams</td>
<td>50 Personally Performed TEE exams</td>
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<tr>
<td>3 Multiple-Choice Exams</td>
<td>NBE Basic PTE Certification Exam</td>
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<td>Two years</td>
<td>Four consecutive years.</td>
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Table 2: Comparison of Basic PTE Certification and proposed Basic PTE Training Program. Simulated TEE exams are not currently recognized by the NBE for the purpose of certification.
The educational methods developed by this proposal will endow the next generation of anesthesiologists with quality TEE training and increase the availability of enhanced perioperative monitoring for an aging surgical population that present with increasing complexity thereby ensuring optimal outcomes for our patients.

References: