Simulation-based transthoracic echocardiography: “An anesthesiologist’s perspective”

Rohan Magoon, Amita Sharma, Suruchi Ladha, Poonam Malhotra Kapoor, Suruchi Hasija
Department of Cardiac Anaesthesia, Cardio Thoracic Centre, All India Institute of Medical Sciences, New Delhi, India

With the growing requirement of echocardiography in the perioperative management, the anesthesiologists need to be well trained in transthoracic echocardiography (TTE). Lack of formal, structured teaching program precludes the same. The present article reviews the expanding domain of TTE, simulation-based TTE training, the advancements, current limitations, and the importance of simulation-based training for the anesthesiologists.

Key words: Anesthesiologist; Simulation training; Simulator; Transthoracic echocardiography

INTRODUCTION

Anesthesiologists have been the pioneers in introducing simulation into medical training. In the 1950s two anesthesiologists, Dr. Peter Safar and Dr. Bjorn Lind developed the first mannequin, Resusci-Annie to teach airway management and resuscitation.[1] Simulation has grown to have an established role in all anesthesia subspecialties over the period, especially in the field of cardiovascular anesthesia.[2]

In the present arena, where the anesthesiologists have assumed the role of perioperative physicians, the utilization of transthoracic echocardiography (TTE) is increasing. Anesthesiologists encounter a variety of emergent situations and may benefit from the applications of TTE. Despite the familiarity with cardiovascular imaging using TEE, the experience of an anesthesiologist with TTE falls much short.

Lack of a formal and well-structured teaching program is a potential cause of the problem. Traditional training is achieved through didactics, observations, and independently performed examinations. However, it is limited by the availability of trainers as well as patients or subjects for performing TTE examination. Moreover, such learning opportunities are episodic, and absence of a graduated exposure from normal to abnormal and simple to complex precludes a meticulous training. Thus, the introduction of simulation in medical training can go a long way to offset the initial learning curve and shorten the training duration.

EXPANDING HORIZONS OF TRANSTHORACIC ECHOCARDIOGRAPHY

The utility of a focused cardiovascular TTE examination during a noncardiac high-risk surgery is well known.[3] Rather it has emerged as a tool for point-of-care decision-making not only within but much beyond the operating room (OR).[4-6] TTE can improve the management...
of these patients owing to it is the ability to dynamically monitor cardiac function and intracardiac chamber pressures.\(^7\) A focused, goal-directed TTE examination, has been shown to alter patient management, and may improve outcomes.\(^4-6\)

Rapidly migrating across the specialty borders as a noninvasive and readily available diagnostic technique, TTE is seeing increased perioperative use by the anesthesiologists as it can assist in decision-making all along the perioperative pathway. A prospective observational study demonstrated that a focused TTE performed by anesthesiologists resulted in alterations in management in 84% of patients and as high as 90% results correlated well with cardiologists’ findings.\(^3\) In the hands of a well-trained anesthesiologist, clinical information may be obtained quickly when sufficient time is lacking in setting of an emergency.

SIMULATION AND TRANSTHORACIC ECHOCARDIOGRAPHY

Echocardiographic image acquisition is an art that involves a complex interaction between an operator, the equipment, and the subject. It entails a thorough understanding of the cardiac anatomy, physiology, and displays through specific imaging windows for one to become proficient in TTE. Repeated mentoring can help the learners acquire standardized reliable images by improving their manual dexterity.

Traditional echocardiographic training of anesthesiologists relies heavily on examinations in the OR, where there is a limitation of time, opportunity for reflection, feedback, training, and is relatively stressful environment. Furthermore, exposure to uncommon clinical scenarios is rather unpredictable, rendering the trainee inefficient in handling such situations proficiently in future. This is where “Simulation” training works as well as “Situation” training.

As a proposed alternative to real-time patient-based learning, simulation-based training allows anesthesiologists to learn much more complex concepts and procedures.\(^2,8-11\)

A recently published review of the impact of simulation on medical education concluded a beneficial effect of on the teaching of basic clinical knowledge as well as communication and procedural skills.\(^12\) Studies have also concluded that simulation-based training is superior to other modes in translating knowledge to improved technical skill.\(^10\) In a similar randomized study design, Neelankavil et al.\(^13\) demonstrated in their study that anesthesia residents showed better interpretation when trained on TTE Simulator (Heartworks, Inventive Medical Ltd., London, United Kingdom), compared to control.

In addition, simulation training can help reinforce and strengthen nontechnical skills such as task management, leadership qualities, team working, situation awareness, and decision-making.\(^14,15\) These skills are vital to patient safety in emergency and crisis situations. Simulation at the same time reduces the extinction of skills.\(^16\)

TRANSTHORACIC ECHOCARDIOGRAPHY SIMULATOR: FROM HEARTWORKS TO VIMEDIX

TTE simulator aims to integrate three-dimensional (3D) anatomic relationships and image acquisition in real time. One side of the screen displays the simulated TTE image, whereas the other side of the screen shows a 3D model of the heart with the path of the transducer. This becomes important as the ability to correlate 3D anatomy and echocardiography is an important component in TTE.

Pivotal remains the correct, solid, 3D model representation of the human heart [Figure 1]. The Heartworks (Inventive Medical Ltd., London, UK) Simulator [Figure 2] essentially remains a tool for learning a normal echocardiographic examination as pathology has not been incorporated into this product. The importance of learning the normal examination as a basis for identifying the pathologies for the beginners cannot be undermined.

Figure 1: Three-dimensional model of the heart
EchoCom (Leipzig, Germany) TTE simulator is based on “augmented reality (AR),” [Figure 3] and aims at coupling a virtual heart with real echocardiographic data acquired from humans.\cite{17, 18}

Blue Phantom (Seattle, WA) simulator consists of a mannequin fitted with a solid, static, and nonbeating model of a human heart that can be interrogated with a surface transthoracic probe. Although the model does not yield a realistic experience for the operator because of the nonphysiological representation.

Vimedix (CEA Healthcare Inc., Montreal, Canada) [Figure 4] is the latest TTE simulator available based on an anatomically correct solid 3D model of the heart. The simulator consists of a realistic mannequin, computer workstation, high-definition monitor, and a dedicated TTE probe. The probe motion is well displayed, and the operator is provided an option to visualize the heart model from multiple angles and a 360° perspective.

The “innovative split view” interface comprises of the “AR” display and the ultrasound display as shown in Figures 2 and 3:

- Right side of the interface shows the 2D ultrasound image with depth of field, contract, gain, M-mode capability and Doppler
- The left side of the interface displays an interactive, animated 3D anatomical depiction of the organs and artifacts in the scanned area.

The image has built in multiple display options (model alone, ultrasound image alone, or side by side viewing). Bestowed with the ability to lock the transducer, move the heart model, or vice versa enhances the educational experience and understanding of the anatomic-echocardiographic image correlation offered.

A simulator should not only be capable of generating a high-quality normal examination but also be capable of simulating a host of common pathologic conditions. TTE imaging can be made even more challenging by altering the orientation of the heart model to mimic an emphysematous or fatty chest with poor windows for examination.

The Vimedix TTE module contains the following pathologies.

- Valvular pathologies
- Dilated cardiomyopathy – severe biventricular systolic dysfunction
- Hyperdynamic left ventricular systolic function
- Recent anterior myocardial infarction
- Pericardial effusion.

**TECHNICAL ENHANCEMENTS**

- “Realistic mannequin:” Life-like features incorporated such as a depressible abdomen, palpable ribs, and abdomen
“Realistic scanning environment:” Renders not only the heart but also all the surrounding structures visible. The visualization of liver, ribs, sternum, superior and inferior vena cava, aorta, lungs, and vertebral bodies can simulate an actual scanning experience

“M-mode imaging:” The ability to display M-mode on any desired section of the heart. During M-mode interrogation, multiple desired chamber measurements can be made by freezing the image

“Linear and area calculations:” Equipped with a caliper function to make linear measurements help conduct all the important hemodynamic calculations

“Target-image” acquisition: Guides the trainees to replicate the transducer movements and angulations performed by an experienced echocardiographer. The software system saves a standardized image acquired by an expert. The trainee then can successfully manipulate the transducer in relation to the saved image. This provides real-time feedback and an opportunity to evaluate the image-acquisition skills

“Depth” and “brightness” adjustment controls

“E-learning opportunities:” Interactive multimedia-based curriculum on website

“Metrics:” Enables the trainees to track his/her image-acquisition skills in reference with standardized expert examination images.

“In the present scenario currently available simulators enables the interrogation of practical skills while evaluating the performance of residents as a competence testing tool.”[19‑21]

Limitations

The absence of color flow and pulse wave Doppler in the currently available simulators precludes the complete evaluation of valvular pathologies. The lack of image optimization controls hampers the “knobology” training for the trainees which is an integral part of TTE examination. The manual dexterity that comes with the repeated handling of the probe is difficult to develop keeping in view the lack of actual tactile sensations. The feature of formally initiate a study by entering virtual patient identification, information, and storing the generated video clips is absent in the present models thereby preventing the conclusion and review the given study. Moreover, there is always an absence of a clinical correlate for the echocardiographic pathological examination and limitation of the inbuilt pathologies. At the same time, there is a major expense attached with the procurement and maintenance of the simulators.

CONCLUSION

Innovative yet user-friendly simulator technology has added a new dimension to the TTE training for anesthesiologists. Simulation provides for increased practice and knowledge integration resulting in much improved, focused TTE skills among anesthesiologists compared to traditional teaching methods. The domain of simulation in echocardiography continues to grow with every passing day due to the amalgamation of necessity, intellectual curiosity, and technological advancements, but central to every step forward remains the improvement in patient management.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Grenvik A, Schaefer J. From resusci-anne to sim-man: The evolution of simulators in medicine. Crit Care Med 2004;32 2 Suppl:S56‑7.
2. Sinz E. Simulation-based education for cardiac, thoracic, and vascular anesthesiology. Semin Cardiothorac Vasc Anesth 2005;9:291‑307.
3. Cowie B. Focused cardiovascular ultrasound performed by anesthesiologists in the perioperative period: Feasible and alters patient management. J Cardiothorac Vasc Anesth 2009;23:450‑6.
4. Beaulieu Y. Specific skill set and goals of focused echocardiography for critical care clinicians. Crit Care Med 2007;35 5 Suppl:S144‑9.
5. Cholley BP, Vieillard-Baron A, Mebazaa A. Echocardiography in the ICU: Time for widespread use! Intensive Care Med 2006;32:9‑10.
6. Mayron R, Gaudio FE, Plummer D, Aisinger R, Elsperger J. Echocardiography performed by emergency physicians: Impact on diagnosis and therapy. Ann Emerg Med 1988;17:150‑4.
7. Manecke GR Jr., Vezina DP. Perioperative transthoracic echocardiography: Universal acid? J Cardiothorac Vasc Anesth 2009;23:447‑9.
8. Matyal R, Bose R, Warraich H, Shahul S, Ratcliff S, Panzica P, et al. Transthoracic echocardiographic simulator: Normal and the abnormal. J Cardiothorac Vasc Anesth 2011;25:177‑81.
9. Bose RR, Matyal R, Warraich HJ, Summers J, Subramaniam B, Mitchell J, et al. Utility of a transesophageal echocardiographic simulator as a teaching tool. J Cardiothorac Vasc Anesth 2011;25:212‑5.
10. Sturm LP, Windsor JA, Cosman PH, Cregan P, Hewett PJ, Maddern GJ. A systematic review of skills...
transfer after surgical simulation training. Ann Surg 2008;248:166-79.
11. Good ML. Patient simulation for training basic and advanced clinical skills. Med Educ 2003;37 Suppl 1:14-21.
12. Okuda Y, Bryson EO, DeMaria S Jr., Jacobson L, Quinones J, Shen B, et al. The utility of simulation in medical education: What is the evidence? Mt Sinai J Med 2009;76:330-43.
13. Neelankavil J, Howard-Quijano K, Hsieh TC, Ramsingh D, Scovotti JC, Chua JH, et al. Transthoracic echocardiography simulation is an efficient method to train anesthesiologists in basic transthoracic echocardiography skills. Anesth Analg 2012;115:1042-51.
14. Yee B, Naik VN, Joo HS, Savoldelli GL, Chung DY, Houston PL, et al. Nontechnical skills in anesthesia crisis management with repeated exposure to simulation-based education. Anesthesiology 2005;103:241-8.
15. Naik VN, Brien SE. Review article: Simulation: A means to address and improve patient safety. Can J Anaesth 2013;60:192-200.
16. Murray DJ. Current trends in simulation training in anesthesia: A review. Minerva Anestesiol 2011;77:528-33.
17. Weidenbach M, Drachsler H, Wild F, Kreutter S, Razek V, Grunst G, et al. EchoComTEE – A simulator for transoesophageal echocardiography. Anaesthesia 2007;62:347-53.
18. Weidenbach M, Wild F, Scheer K, Muth G, Kreutter S, Grunst G, et al. Computer-based training in two-dimensional echocardiography using an echocardiography simulator. J Am Soc Echocardiogr 2005;18:362-6.
19. Montealegre-Gallegos M, Mahmood F, Kim H, Bergman R, Mitchell JD, Bose R, et al. Imaging skills for transthoracic echocardiography in cardiology fellows: The value of motion metrics. Annals of Cardiac Anaesthesia 2016;19:245-50.
20. Malik V, Subramaniam A, Kapoor PM. Strain and strain rate: An emerging technology in the perioperative period. Annals of Cardiac Anaesthesia 2016;19:112-21.
21. Kapoor PM. Echocardiography for cardiac tamponade. Annals of Cardiac Anaesthesia 2016;19:338.