Can Simulation Help to Answer the Demand for Echocardiography Education?

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ABSTRACT

There has been a recent explosion of education and training in echocardiography in the specialties of anesthesiology and critical care. These devices, by their impact on clinical management, are changing the way surgery is performed and critical care is delivered. A number of international bodies have made recommendations for training and developed examinations and accreditations.

The challenge to medical educators in this area is to deliver the training needed to achieve competence into already overstretched curricula.

The authors found an apparent increase in the use of simulators, with proven efficacy in improving technical skills and knowledge. There is still an absence of evidence on how it should be included in training programs and in the accreditation of certain levels.

There is a conviction that this form of simulation can enhance and accelerate the understanding and practice of echocardiography by the anesthesiologist and intensivists, particularly at the beginning of the learning curve. (Anesthesiology 2014; 120:32-41)

The advent of cardiac ultrasound imaging devices in critical care units and operating rooms has been a huge cultural change. In addition to point of care diagnosis, the patient and clinician can also benefit from augmented hemodynamic monitoring giving additional information to conventional pressure and flow-based measurement.1–6

The size, portability, ease of use, and the high quality of the imaging has made the case for widespread international adoption undeniable. Ultrasound is technical and operator dependent with a significant learning curve. Anesthesiology and critical care educators the world over are grappling with the same thorny problem: how to get a cohort of trainees to achieve clinical competence in a new technical skill within a time-limited training program that is already packed. The significant implications of this are the manpower, expense, and time required for supervision and training. An in-depth knowledge of anatomy and the technical aspects, together with awareness of the multiple clinical scenarios and implications for management mean the supervised acquisition of experience is essential to avoid serious error.7–9

Early adopters of echocardiography for specialist practice in areas such as cardiac anesthesiology and coronary critical care were very much bound to cardiologists for training and supervision until these specialties evolved more autonomy in training and governance. Various systems of echocardiography education, training, and accreditation have subsequently been established in a number of countries, mostly overseen by professional bodies. Examinations have evolved together with a defined log book of case mix and case load. This has spawned multiple teaching modalities encompassing book publishing, medical rotations, echocardiography laboratory attachments, theoretical and practical courses, and clinical case-based learning.

Echocardiography is primarily a visual medium and images are universally stored as digital video files. This has made access to online echocardiography training and digital image libraries readily and easily available to augment the experience of bedside training.

The latest significant development in training has been the emergence of echocardiography simulators. Simulators are widely used in other areas of science and industry to enhance performance of procedures requiring skill and precision. Simulators have been rapidly and widely adopted into medical and surgical training. They have allowed the repetition of diverse scenarios, high risk in some cases, rare and infrequent in others, to improve performance at the clinical sharp end. Ultrasound simulators in particular have expanded the opportunities for learning and acquisition of skills. Technical and manual skills can be improved with the use of high-fidelity probes and mannequins; a wide range of artifacts and pathological conditions can be taught; most importantly, echocardiographic anatomy and imaging planes can be related to topographical anatomy.
In this review, we attempt to synthesize the experience of three European centers with the published evidence, to develop a global perspective of the demand for echocardiography education. We also investigate the evidence for the inclusion of simulation in echocardiography education programs. We searched the Internet to identify all anesthesiology, critical care, and echocardiography professional bodies and identified all available information in regard to accreditation and education programs. We also searched the most current scientific evidence by searching the U.S. National Institutes of Health, National Library of Medicine (MEDLINE) using the key words: simulation, echocardiography, echocardiography education, anesthesiology, and critical care.

The Learning Process

Two levels of competence are generally defined for emergency, intraoperative, and critical care echocardiography—basic and advanced. The basic level has a relatively short learning curve and is designed to answer simple clinically relevant questions. The basic examination essentially uses two-dimensional ultrasound and is structured around a yes/no binary response, for example, “left ventricle dilated/nondilated and function abnormal/normal” or “tamponade present/not present.”

The advanced level requires broader and deeper knowledge including spectral and color Doppler in addition to an appreciation of a wide range of abnormalities and their classification and quantification. The learning curve is longer and steeper, and a profound understanding of cardiac physiology is needed. Furthermore, a certain amount of time is required to gather appropriate experience of the clinical context within which the examination is performed, whether it is in the acute medical unit, the cardiac operating room, the critical care unit, or the emergency room of a trauma unit.

Over the past decade several scientific societies and professional bodies have embraced this explosion of ultrasound and have designed and overseen minimum learning curricula. There is a profound responsibility that falls on both these bodies and the individual practitioner to operate with appropriate governance and supervision, particularly during this initial learning period. The impact of decision making on patients in the acute medical specialties is often immediate and potentially life threatening.

The American Society of Anesthesiologists together with the Society of Cardiovascular Anesthesiologists and the American Society of Echocardiography were the pioneers who first established the process by which formal training and assessment enabled cardiac anesthesiologists to attain the necessary recognition to become high-level echocardiographers and improve the perioperative diagnosis and management of cardiac surgical patients.

The success of this achievement and its widespread adoption and international replication led the way for the development of critical care and postoperative physician-delivered echocardiography and the concept of general ultrasound in critical care. The documents published by the American College of Chest Physicians with La Société de Réanimation de Langue Française and the World Society Interactive Network Focused on Critical Ultrasound presented in detail a suggested syllabus for ultrasound in critical care (fig. 1). These have been firmly evidence-based with a comprehensive concept of appropriate training. A number of other national societies have followed with their own schemes to accommodate differing priorities and the organization of each healthcare system.

Simulation in Medicine

The aviation industry has long led the way in the use of simulation to mitigate the risk of disasters. Simulation can enable the analysis of human behavioral factors while performing complex tasks under stressful conditions with consequent learning and performance improvement. The appearance of simulators in medicine and surgery has followed apace, in particular for difficult clinical scenarios in acute and emergency care areas.

Medical simulation can be broadly divided into two types:

1. Team simulation—where situational awareness, human interaction, and cognitive improvement are the priority;
2. Technical simulation—where safe repetitive practice of an individual technical skill is the focus.

The primary goal is improved performance of the team and individual, with improved outcome for patients being the ultimate goal. Clearly, the higher the fidelity of the simulation, the greater the immersion in the experience, the greater the value to the trainee. Validation of the simulation against reality is therefore essential.

The use of simulators for surgical training is a good example of technical simulation and has been important for the safe development of minimally invasive surgery, endoscopy, and laparoscopic surgery. As experience has evolved and the simulators have become ever more sophisticated, surgeons have benefitted from shortened learning times, improved outcomes, and reduced complication rates. Echocardiography simulation too is a technical type of simulation.

Echocardiography Simulators

Technology

In anesthesia and critical care, the heart, lungs, and aorta are the structures of interest and are what we consider here. To
Simulation for Echocardiography Education

Anesthesiology 2014; 120:32-41

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Cater for the ever-increasing demand for simulation in echocardiography a range of simulation devices are on the market and have been studied by various investigators. The recent article by Shakil et al.\(^5\) provides a comprehensive review of the available technologies. Table 3 summarizes the salient features of currently available echocardiography simulators. Heartworks (Inventive Medical, London, United Kingdom) and Vimedix (CAE Healthcare, Quebec, Canada) simulators are the two most popular among the commercially available echocardiography simulators and offer the best range of features. Both consist of a high-end software-loaded computer and screen, a mannequin, and dummy probes. Transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE) simulation dummy probes are available on both versions. The TEE simulation probe has possibly the greater value as it is a semi-invasive procedure—TTE is a noninvasive body surface procedure and can be taught more easily on live subjects. The displays consist of a three-dimensional (3D) anatomical model of the beating heart that can be manipulated with an indicator of the probe

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**Table 1. Critical Care Echocardiography Accreditations**

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Body</th>
<th>TTE/TEE</th>
<th>Structure</th>
<th>Assessment</th>
<th>Logbook</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>FICE basic</td>
<td>BSE/ICS</td>
<td>TTE</td>
<td>Course, logbook, triggered assessment</td>
<td>Clinical</td>
<td>50</td>
<td>6 months</td>
<td></td>
</tr>
<tr>
<td>AACCE advanced</td>
<td>BSE/ICS</td>
<td>TTE</td>
<td>MCQ exam logbook, video logbook</td>
<td>Exam logbook scoring</td>
<td>250</td>
<td>2 yr</td>
<td></td>
</tr>
<tr>
<td>FEEL basic</td>
<td>Various national</td>
<td>TTE</td>
<td>Logbook</td>
<td>NS</td>
<td>50</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>FATE basic</td>
<td>FATE protocol</td>
<td>TTE</td>
<td>Course</td>
<td>Exam</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Level 1 basic</td>
<td>ASE/ACC</td>
<td>TTE</td>
<td>Logbook</td>
<td>NS</td>
<td>150</td>
<td>3 months</td>
<td></td>
</tr>
<tr>
<td>Level 2 advanced</td>
<td>ASE/ACC</td>
<td>TTE</td>
<td>Logbook</td>
<td>NS</td>
<td>300</td>
<td>6 months</td>
<td></td>
</tr>
<tr>
<td>Basic CCE</td>
<td>ESICM</td>
<td>TTE</td>
<td>Course</td>
<td>Logbook</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Level 1 basic</td>
<td>WINFOCUS</td>
<td>TTE and TEE</td>
<td>Course and supervision</td>
<td>Logbook</td>
<td>250</td>
<td>2 yr</td>
<td></td>
</tr>
<tr>
<td>Level 2 advanced</td>
<td>WINFOCUS</td>
<td>TTE and TEE</td>
<td>Course and supervision</td>
<td>Logbook</td>
<td>250</td>
<td>2 yr</td>
<td></td>
</tr>
</tbody>
</table>

Summary of the different accreditations in critical care echocardiography, with the scientific societies that endorse it, and requirements necessary to complete it.

AACCE = Adult Accreditation in Critical Care Echocardiography; ACC = American College of Cardiology; ASE = American Society of Echocardiography; BSE = British Society of Echocardiography; CCE = critical care echocardiography; ESICM = European Society of Intensive Care Medicine; FATE = focused assessed transthoracic echocardiography; FEEL = focused emergency echocardiography live support; FICE = focused intensive care echo; ICS = Intensive Care Society; MCQ = multiple-choice questions; N/A = not available; NS = unspecified; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; WINFOCUS = World Interactive Network Focusing on Critical Care Ultrasound.
position and ultrasonic imaging plane alongside a simulated grayscale echocardiographic image. A considerable body of anatomical and animation expertise has contributed to the models. The echocardiographic plane and heart model will vary corresponding to alterations in probe orientation, called the haptic interface. The 3D anatomical model can be rotated and zoomed, surface anatomy can be “clicked” and removed to reveal the structure of the deeper lying valves. The motion of the chambers and contraction can be slowed and analyzed. Programmed pathological conditions can be selected in addition to normal anatomy. There is interactive text to support the visual displays. Both platforms support the use of self-directed learning, although some expert tuition is required to enhance the learning experience. The manufacturers are regularly updating their systems and adding improvements. Overall, the Heartworks system possibly has the better anatomical model of the heart and the more realistic grayscale echocardiographic image. The Vimedix has a larger library of pathological conditions and has a color Doppler function. The Vimedix also now incorporates a system of metrics, which enables the trainee to measure his or her performance.

Table 2. TEE Accreditations

<table>
<thead>
<tr>
<th>Name</th>
<th>Body</th>
<th>Structure and Assessment</th>
<th>Logbook No</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perioperative TEE</td>
<td>ASE/SCA</td>
<td>MCQ exam logbook scoring</td>
<td>150 basic 300 advanced</td>
<td>1 yr/2  yr</td>
</tr>
<tr>
<td>Adult TEE</td>
<td>EACTA/EACVI</td>
<td>MCQ exam logbook scoring</td>
<td>125</td>
<td>1 yr</td>
</tr>
<tr>
<td>Adult TEE</td>
<td>BSE/ACTA</td>
<td>MCQ exam logbook scoring</td>
<td>125</td>
<td>2 yr</td>
</tr>
<tr>
<td>Adult TEE</td>
<td>SEDAR</td>
<td>Clinical attachment</td>
<td>95 + 100 TTE</td>
<td>3 months</td>
</tr>
</tbody>
</table>

Summary of the different accreditations in TEE, scientific societies that endorse it, and requirements necessary to complete it.

ACTA = Association of Cardiothoracic Anaesthetists; ASE = American Society of Echocardiography; BSE = British Society of Echocardiography; EACTA = European Association of Cardiothoracic Anaesthetists; EACVI = European Association of Cardiovascular Imaging; MCQ = multiple-choice questions; SCA = Society of Cardiovascular Anaesthetists; SEDAR = Spanish Society of Anesthesiology; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

Simulation for Spatial Orientation in Echocardiography

Cardiac anatomy is complex, with the added difficulty of cardiac motion and it is often a quantum step from undergraduate concepts to the understanding required for echocardiographic anatomy. Individual brains differ in their ability to construct and appreciate 3D maps using only two-dimensional images. The study of echocardiographic anatomy is best undertaken by first building an accurate mental image of the heart and correlating two-dimensional planar images with this abstract 3D figure. It is important to have landmarks to provide spatial orientation from multiple viewpoints, much the same as a map can represent a guide for travellers.

Echocardiography is necessarily a dynamic assessment and it is important to examine the structures throughout the cardiac cycle. A TTE study includes parasternal, apical, and subxiphoid views of the heart with subtle manipulation of the transducer in each position. A TEE study explores the heart from four locations (high esophagus, mid esophagus, transgastric, and deep transgastric) with rotation of the transducer plane between 0 and 180 degrees. TTE-derived images are displayed on a screen with the right-sided structures on the left and the anterior structures nearest to the apex of the sector. TEE-derived images similarly display left-sided structures on the right of the screen with posterior structures uppermost. These complexities and the difficulty in correlating TTE with TEE can mean that echocardiographic anatomy is completely baffling to the novice. This then is the great advantage of the simulator—expert bedside teaching, fastidious study of texts, and digital images and lectures cannot present the student with such an elegant method of anatomical correlation.

Three-dimensional echocardiography has been a reality now for a number of years in operating rooms and catheter laboratories. Initially the technique requires time-consuming image acquisition, reconstruction off-line, and poor-quality images can limit its utility. Some of these limitations can be overcome by increasing exposure to the technical aspects of real-time 3D. Simulation is useful here too, to accelerate the learning process not only in image acquisition but also in using the correct knobology. Those practitioners who subspecialize in pediatric cardiac anesthesia may also benefit from somewhat more specific simulation in this area.

Transducer manipulation may also be taught with the simulator, its feel, weight, and angulation to the skin or esophagus, essential for image optimization. This is all the more important in TEE, where a clumsy or inexperienced trainee has the potential to cause significant harm. Whereas image interpretation can be discussed in a more leisurely manner, obtaining an image set in a timely manner is important in a clinical scenario. Again, the simulator can advance the ability to get through a study in an efficient yet high-quality manner.

A less hands-on, but certainly less costly way to access simulation is via online simulation. A recently developed simulation tool demonstrates how the 20 main planes are mapped to a 3D cardiac animation. Early studies have demonstrated that significant improvements in trainees’ knowledge can result from a relatively short exposure to this simulation. Clearly this can be incorporated into a training program as a self-directed learning episode.
As discussed, echocardiography is increasingly used for operating room and bedside hemodynamic monitoring in various clinical scenarios. Integration of clinical examination, imaging findings, data obtained from other monitors, and the appropriate changes in management is an important part of training.67–70 The simulation software can display changes such as cardiac chamber volumes, contractility, pathological valvular conditions, pericardial compression, and cardiac arrest. These can be integrated into simulation scenarios in the high-fidelity anesthesia or critical care simulation laboratory; thus both technical, cognitive, and behavioral responses to acutely unstable patients with abnormal echocardiographic findings can be evaluated. The echocardiographic simulator would seem to fit perfectly with a recently introduced simulator of the cardiopulmonary bypass machine. Thus the cardiac surgical operating room can be replicated accurately in the simulation laboratory. There is a dearth of evidence as yet to support this model, but intuitively this would seem an engaging way for the budding anesthetic echocardiographer to acquire leadership skills for the operating room.71–73

### Echocardiography Simulation in Educational Programs

Simulators have been introduced into many educational programs. It is obviously easier to construct a TTE course using simulators alongside models, real TEE can only be demonstrated on real patients as part of clinical practice. As it can be difficult to provide focused TEE teaching at the same time as managing the patient’s needs, TEE simulation

#### Evidence for Effectiveness of Echocardiography Simulation

Several investigators and experts regard the use of echocardiographic simulation as an enhancement and an accelerator to traditional learning programs.63–66 A comprehensive description of these studies is beyond the scope of this review; their key features and findings are summarized in table 4. Although most of these studies are underpowered due to the limited sample size, the individual results in these studies highlight a high level of compliance and satisfaction among trainees with the simulation process. Furthermore, all the studies of effectiveness of simulation-based echocardiography training compared with conventional methods such as lectures and literature review reveal a significant improvement of knowledge in echo-naive trainees. All these studies advocate the use of simulation as a desirable adjunct to the conventional methods of learning. Most investigators and trainers would still consider hands-on real-time intraoperative image acquisition and teaching as the “definitive standard” for echocardiography learning. The recent introduction of pathological features such as aortic and mitral valve disease in simulation software is a significant step forward.

### Echocardiography Simulation in Clinical Scenarios

As discussed, echocardiography is increasingly used for operating room and bedside hemodynamic monitoring in various clinical scenarios. Integration of clinical examination, imaging findings, data obtained from other monitors, and the appropriate changes in management is an important part of training.67–70 The simulation software can display changes such as cardiac chamber volumes, contractility, pathological valvular conditions, pericardial compression, and cardiac arrest. These can be integrated into simulation scenarios in the high-fidelity anesthesia or critical care simulation laboratory; thus both technical, cognitive, and behavioral responses to acutely unstable patients with abnormal echocardiographic findings can be evaluated. The echocardiographic simulator would seem to fit perfectly with a recently introduced simulator of the cardiopulmonary bypass machine. Thus the cardiac surgical operating room can be replicated accurately in the simulation laboratory. There is a dearth of evidence as yet to support this model, but intuitively this would seem an engaging way for the budding anesthetic echocardiographer to acquire leadership skills for the operating room.71–73

#### Table 3. An Overview of Currently Available Echocardiography Simulators

<table>
<thead>
<tr>
<th>Simulator</th>
<th>Initial Studies</th>
<th>Image Acquisition and Display</th>
<th>Hands-on</th>
<th>Clinical Scenarios</th>
<th>Internet-based Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>HeartWorks</td>
<td>Bose et al.⁵⁰</td>
<td>Virtual reality; computer digital reconstruction (grayscale images) from a beating heart model</td>
<td>Yes, TEE and TTE</td>
<td>Available</td>
<td>Not available</td>
</tr>
<tr>
<td>VIMEDIX</td>
<td>Piatts et al.⁶⁶</td>
<td>Virtual reality; computer-based digital reconstruction (grayscale images) from a beating heart model</td>
<td>Yes, TEE and TTE</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>EchoCom TEE</td>
<td>Weidenbach et al., Germany, 2007</td>
<td>Augmented reality; real-time 2D image derivation from a beating heart model and 3D TTE data set</td>
<td>Yes, TEE</td>
<td>Available</td>
<td>Not available</td>
</tr>
<tr>
<td>VirSim TEE simulator</td>
<td>Song et al.⁷⁰</td>
<td>Augmented reality; real-time 2D image derived from TEE data</td>
<td>Yes, TEE</td>
<td>Available</td>
<td>Not available</td>
</tr>
<tr>
<td>Virtual TEE and TTE</td>
<td>Jerath et al.⁶⁴</td>
<td>Virtual reality; real-grayscale images of 20 standard TEE and TTE views</td>
<td>No</td>
<td>Not available</td>
<td>Available</td>
</tr>
<tr>
<td>CT2TEE Simulator</td>
<td>Piorkowski and Kempny⁴⁸</td>
<td>Virtual reality; grayscale images from ECG-triggered CT data sets</td>
<td>No</td>
<td>Not available</td>
<td>Available</td>
</tr>
</tbody>
</table>

Characteristics of the various available simulators in echocardiography, promoters, and developers.

CT = computed tomography; CT2TEE = computed tomography to transesophageal echocardiography; ECG = electrocardiogram; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; VirSim = virtual simulator; 2D = two dimensional; 3D = three dimensional.
can provide opportunities for dedicated teaching away from the stress of clinical interaction. There is a lack of published evidence to suggest whether one learning strategy is better than another, but simulation may allow faster, more effective acquisition of technical skills in a dedicated teaching environment. Although there is some published evidence that 30 supervised studies are sufficient for basic competence in TEE, it would be very interesting to determine the effect of including simulation into the teaching program. Anesthesia senior residents and year 1 to 2 level surgical residents who have been exposed to simulation training from the start of their residencies are much more likely to use their institution’s simulation center than year 3 to 5 level residents who began simulation training after having spent some time in the operating room. This is likely the result of a disaffection for the unreality of simulation compared with the reality of the operating room. Sufficient grounds possibly to introduce simulation earlier into training programs?

The emphasis is now shifting from the technology of simulation toward partnership with education and clinical practice. Video and Web-based simulations are examples of low-fidelity systems yet highly accessible and low-cost, which may serve to train large numbers of people simultaneously. We have argued in this article that small group simulation with a dummy and the haptic interface is both useful and efficient in the acquisition of ultrasound skills.

So the question is when to use high-fidelity simulators and when to use lower-fidelity applications in the training pathway? Once again there is no compelling evidence as yet, but we may hypothesize that the latter should be used in the initial phase and first-contact training and the former in subsequent stages of training.

Conclusions

Many undergraduate medical schools and postgraduate institutions around the world are now equipped with advanced simulation centers. Ultrasound has now established itself as a tool whose use in various procedures performed in critical care and anesthesia, for example, regional nerve blocks and central

![Fig. 2. Heartworks simulator showing display screen, mannequin, and dummy transesophageal echocardiography probe. Heartworks simulator © Inventive Medical Ltd, London, United Kingdom. Used with permission.](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/930986/)

![Fig. 3. The CAE Vimedix echocardiography simulator showing screen, mannequin, and three types of dummy probes. CAE Vimedix simulator © CAE Healthcare (formerly Canadian Aviation Electronic), Quebec, Canada. Used with permission.](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/930986/)
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Table 4. An Overview of the Scientific Publications Details about Echocardiography Simulators

<table>
<thead>
<tr>
<th>Author (yr)</th>
<th>Participants (n)</th>
<th>Study Type</th>
<th>Modality Studied</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weidenbach et al. 53</td>
<td>56 (25 experts and 31 novice users)</td>
<td>Questionnaire-based survey</td>
<td>EchoCom TEE</td>
<td>Experts rated the simulator as realistic, and novice users felt that it supported spatial orientation</td>
</tr>
<tr>
<td>Bose et al. 50</td>
<td>14</td>
<td>Prospective randomized; benefit assessed using pre- and posttests</td>
<td>HeartWorks TEE simulator</td>
<td>Simulator-based teaching is better than conventional methods of TEE teaching</td>
</tr>
<tr>
<td>Jerath et al. 64</td>
<td>10</td>
<td>Prospective observational; benefit assessed using pre- and posttests</td>
<td>Virtual TEE Web site; standard views module</td>
<td>Significant improvement in knowledge of cardiac anatomy on TEE after review of the Web site</td>
</tr>
<tr>
<td>Vegas et al. 62</td>
<td>10</td>
<td>Prospective observational; benefit assessed using pre- and posttests</td>
<td>Virtual TEE Web site; simulation module</td>
<td>Use of simulation module significantly improves knowledge of navigating 20 standard TEE views</td>
</tr>
<tr>
<td>Platts et al. 66</td>
<td>82 (42 trainee sonographers and 42 attendees at TEE workshop)</td>
<td>Prospective observational; assessed using questionnaire-based survey</td>
<td>VIMEDIX TTE and TEE simulator</td>
<td>Simulation provides a realistic method of image acquisition and improves spatial relationship</td>
</tr>
<tr>
<td>Neelankavil et al. 63</td>
<td>61</td>
<td>Prospective randomized; effect assessed using pre- and posttests and TTE examination on volunteers</td>
<td>HeartWorks TTE simulator</td>
<td>Simulation-based teaching significantly improves TTE image acquisition and anatomical identification as compared with lecture-based methods</td>
</tr>
<tr>
<td>Sharma et al. 65</td>
<td>28</td>
<td>Prospective randomized; benefit assessed using pre- and posttests</td>
<td>Virtual TEE Web site and HeartWorks TEE simulator</td>
<td>Internet- and simulation-based teaching significantly improves TEE knowledge when compared with traditional methods</td>
</tr>
</tbody>
</table>

Published scientific evidence of the various models of echocardiography simulators commercially available.

EchoCom = copyright of echocardiography simulator from Weidenbach et al. (Leipzig University), Germany; HeartWorks = copyright of echocardiography simulator from Inventive Medical Ltd., London, United Kingdom; TEE = tranesophageal echocardiography; TTE = transthoracic echocardiography; VIME-DIX = copyright of echocardiography simulator from CAE Healthcare, Quebec, Canada.

vein cannulation, improves safety for patients.77,78 It has been further demonstrated that simulation of these ultrasound-led procedures can improve performance and reduce complications.79–81 Echocardiography and its interpretation in the acute setting is a much more complex ultrasound-based activity, and performance and outcomes are not easily measured. There is concern that the rapid increase in enthusiasm can produce unregulated “have a go hero,” with resulting increases in adverse incidents and litigation. It would seem that it is important that medical educator’s attention is now focused on research in this area. From the experience in our own institutions and educational programs for scientific societies across Europe, we believe that addition of echocardiography simulation to postgraduate curricula, accreditation, and fellowship programs will enhance and accelerate the theoretical and the practical components that produce competency.

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Competing Interests

The authors declare no competing interests.

References


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35. Lineberry M, Walwanis M, Reni J; Naval Air Warfare Center Training Systems Division: Comparative research on training simulators in emergency medicine: A methodological review. Simul Healthc 2013; 8:253–61


46. Horster S, Stemmler HJ, Serraller J, Tischer J, Hausmann A, Geiger S: Mechanical ventilation with positive end-expiratory pressure in critically ill patients: Comparison of CW-Doppler...
ultrasound cardiac output monitoring (USCOM) and thermo
dilution (PiCCO). Acta Cardiol 2012; 67:177–85