

Echocardiography Simulation – A Powerful Educational Tool

Dr. Nick Fletcher examines using simulation as an educational and training tool to enhance competence in Echocardiography.

Physician use of echocardiography in intensive care, anaesthesiology, acute and emergency medicine is becoming more widespread and is recognized to be one of the key development areas for the upcoming generation of clinicians. In addition to point of care diagnosis, echocardiography can guide interventions and is complementary to many of the existing forms of monitoring. More affordable, compact and portable echocardiography machines with good quality transthoracic (TTE) and transesophageal (TEE) probes are now available.

Many of the technological barriers to adoption have therefore been lifted; however the problem of physician education remains an issue. Echocardiography is a technical skill with a significant knowledge base. For an individual to gain competence even in basic focused echocardiography will take six months. Those with the ambition to educate trainees to gain this competence are trying to work out how to achieve this within a time limited and constantly expanding medical curriculum. The manpower, expense

and time required for supervision and training is considerable. Echocardiography simulation as a means to accelerate and enhance traditional clinical teaching is therefore an appealing prospect¹. This article will look at how this might be achieved and discuss some of the concepts involved.

Echocardiography in Anaesthesia and Intensive Care

Echocardiography has been utilized as a diagnostic modality for a long time in cardiac anaesthesia, critical care and emergency medicine, but was performed by cardiologists and trained echocardiography technicians. More recently, focus has been on delivery by clinicians themselves. Training has been broadly defined as either basic or advanced². Basic competence encompasses mostly a limited set of 2D transthoracic imaging planes to diagnose severe and potentially life threatening pathology, otherwise referred to as focused echocardiography. Advanced practice utilizes a full range of anatomical and Doppler imaging via TTE or TEE to diagnose pathologies and monitor hemodynamic interventions.

Echocardiography Protocols

Various protocols have developed in different regions and differing areas of practice. This concept was pioneered by Professor Eric Sloth and the Aarhus group in the late 1980s. These are focused applications of echocardiography, with the addition of lung or abdominal ultrasound depending on the context. The underlying principle is that of a timely limited scan for major pathology to expedite immediate intervention. Expert assessment can take place once the patient has been stabilized. These protocols

Above
**Mitral
Regurgitation.**

All Images:
Inventive Medical.

are specifically designed with the trainee in mind and some have an embedded curriculum, supervision, educational content and a competency sign off. See Table 1 for further details.

Advanced Echocardiography

Cardiac anaesthetists were the first non-cardiology specialty to adopt echocardiography in a serious way. Competency in intraoperative TEE for diagnosis and monitoring of the cardiac surgical patient has now become essential for all specialist practitioners. Cardiac anaesthetists in different regions of the world have evolved systems of accreditation and training to develop the required level of competency. Intensive Care clinicians are now developing their own systems of accreditation adapted to the specialized needs of their patients.

Simulation

Simulation in medicine has long been used as an educational and interventional tool. Training in medical emergencies has always been problematic as it is

Name	Echocardiography views	Context	Other content	Number of scans required for certification
FATE	PLAX, PSAX, A4C, SC4C, pleura	Postoperative cardiac surgery, ICU	M-mode Pleural views for effusion	Not applicable
FAST	PLAX, SC4C	Trauma, EM	Pleural views Abdominal views	
FEEL	PLAX, PSAX, A4C, S4C	Resuscitation	No	50 supervised scans
FICE	PLAX, PSAX, A4C, S4C, SCIVC 2D only	ICU, EM	Pleural views for effusion	50 supervised scans

FATE - Focused Assessed Transthoracic Echocardiography; FAST - Focused Assessment of Trauma; FEEL - Focused Echocardiography in Emergency Life support; FICE - Focused Intensive Care Echocardiography, EM - Emergency Medicine. PLAX - parasternal long axis; PSAX - parasternal short axis; A4C - apical 4 chamber; SC4C - subcostal 4 chamber; A2C - apical 2 chamber; A5C - apical 5 chamber; SCIVC - subcostal inferior vena cava; A3C - apical 3 chamber; RV - right ventricle

rarely possible to pause and analyze performance without affecting the outcome for the patient. The controlled environment of the simulation centre allows repetition, observation and analysis of performance in these scenarios. The objective is to improve performance which can then be translated to the clinical arena for real clinical outcome benefits for patients. Simulation can also be used to teach and improve performance of technical procedures such as laparoscopic surgery. With increasing technological sophistication, high fidelity simulator technology has become widely available in the developed world. Simulation can broadly be divided into that used to improve human factors and that used to improve technical skills. Echocardiography simulation has

Above
Table 1.
Summary of
commonly
used focused
echocardiography
protocols.

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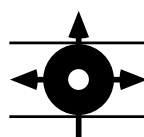
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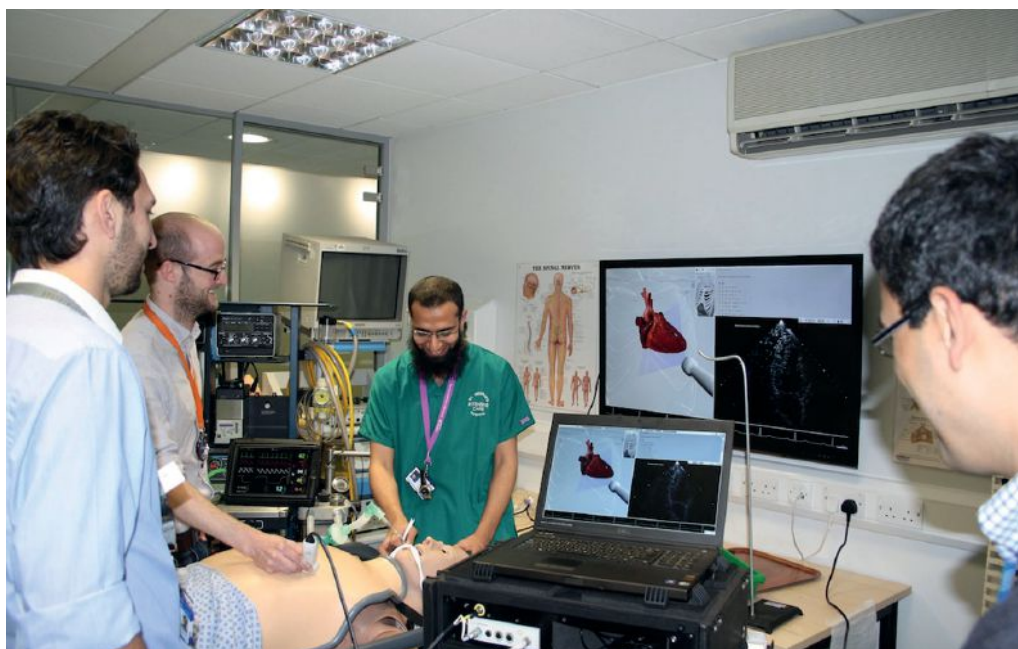
thus far fallen into the category of technical simulation.

Technology

Appreciation of sonographic anatomy is the key step to an understanding of echocardiography. Echocardiography simulation has been developed specifically to enhance and accelerate this anatomical appreciation¹. The simulator is an elegant solution to the problem of relating cardiac anatomy and imaging planes to topographical anatomy and probe position. This is particularly relevant in the case of the 'echo naïve' trainee. The three dimensional appreciation is a cognitive process that cannot readily be obtained from clinical teaching. There are two types of echocardiography simulator: web based platforms and mannequin based platforms.

Web based simulators are remotely accessed, readily accessible and are essentially user directed. Some available versions have a 3D steerable heart model associated with either real or graphic greyscale images, e.g. Toronto Virtual TEE and TTE. Applications are available for tablets and smartphones enabling users to bring the simulation to the ward or operating theatre. An educational package is associated with each of these programs.

Mannequin based platforms consist of a mannequin and dummy ultrasound probe interfaced with a computer with an advanced graphics package and a high resolution large screen. They are generally used in a small group teaching session supervised by an expert operator. There is a learning curve associated with the use of the simulator itself, but a student can direct their own learning after some initial instruction. A dummy TTE or TEE probe is manipulated in relation to the mannequin in exactly the same way as a real echocardiographic study. A haptic interface senses the probe position on the mannequin and the 3D beating heart model displays the ultrasound sector with the corresponding greyscale image. A considerable degree of medical and animation experts have contributed to the development and evolution of the models. The most widely used commercially available models are HeartWorks (Inventive Medical, London, UK) and Vimedix (CAE Healthcare, Quebec, Canada).



Above
TTE mobile simulation.

These simulators have both TTE and TEE replica probes and anatomically accurate mannequins. The simulators have evolved from their initial configurations to include 2D, M-mode, pulsed wave, continuous wave Doppler and colour flow Doppler. A large number of pathological conditions including valvular and ventricular disease have also been skillfully replicated as teaching options. There is an extensive e-learning package associated with both these simulators with self-assessment options.

Is Echocardiography Simulation an Effective Educational Tool?

Echocardiography simulation has been commercially available now for 10 years. This period is sufficient for the accumulation of a body of educational research to attempt an answer to the question posed above. These studies have mostly compared the value of traditional educational resources (texts, didactic lectures) with simulation to identify basic echocardiographic anatomical planes. These small scale studies have mostly been with echo naïve trainee anaesthetists using TEE. However there is good agreement between these international researchers that the echocardiography educational benefit conferred by simulation is significantly greater than conventional educational aides³. Utilizing the pre-intervention and post-intervention

testing method researchers have demonstrated better image recognition in those groups that had learned anatomical and spatial concepts with echocardiography simulation.

A recent study has gone further and demonstrated that in the same context, the HeartWorks simulator is superior to in-theatre clinical echocardiography teaching for the acquisition of basic TEE knowledge⁴. In addition, these studies highlight a high level of compliance and satisfaction among trainees with the simulation process. Part of this effect may well be due to the high quality focused interaction between expert tutors and learners away from the pressures of the clinical frontline. Several investigators and experts have concluded that the use of echocardiographic simulation may serve as an enhancement and an accelerator to traditional learning programs. It must be remembered that we are discussing the very early and steep part of the learning curve; the clinical applications of echocardiography are necessarily learnt at the bedside or in the operating theatre.

Educational Programs

The increasing availability of high fidelity echocardiography simulators and trainers and the pressure to develop competent point of care echocardiography physician practitioners has resulted in an increasing evidence base for adoption. All of the critical care program directors in a recent survey in the US considered simulation to be an essential part of an ultrasound teaching program. Most of

the evidence for cardiac ultrasound simulation comes from cardiac anesthesia TEE teaching program research. This is partly due to the fact that TEE is more invasive and also that it is already well established and embedded in cardiac anesthesia programs. There is less research with TTE as used for critical care, possibly as it can be demonstrated with real human models. The studies are in the main randomized and underpowered and are in trainees at an early point in the learning curve. Nevertheless, the consistent finding of the benefit of simulation is impressive and it is possible to translate this into general critical care – echocardiography training in cardiac critical care overlaps with cardiac anesthesia.

It has been shown that only 12% of the concepts taught in an oral session of an ultrasound course are retained within two weeks. Hands on clinical teaching of echocardiography skills on patients will always remain the principal route to competence. Manipulation of the probe is a fundamental skill. Acquisition of probe manipulation skills using TEE is more difficult than TTE due to the potential for harm and the lack of willing volunteer models!

Significance for Educational Programs

The concept of competence is now widely embedded in medical education. This will usually incorporate a curriculum of knowledge and skills, defined methods of assessment and a sign off. The process will be overseen by a supervisor with the necessary qualifications and experience to assume the role. Discussion still remains whether this should be time based or caseload based. Trainee feedback is vital in ensuring the process continually evolves.

Whereas a number of international curricula in critical care and emergency medicine have embedded ultrasound guided vascular access, the same cannot be observed for echocardiography - the

learning curve is longer and competence is more difficult to achieve. Most echocardiography curricula remain an additional competence which the motivated trainee may choose to acquire. This state of affairs is rapidly evolving with different solutions across the world. Most accreditations and commentators have adopted a caseload based logbook. There is a variation in the numbers required. The question we need to ask here is – would the inclusion of high fidelity simulation into the echocardiography curriculum help to shorten the learning curve? The accumulated evidence above suggests that it would, albeit when introduced at an early stage.

HeartWorks has been utilized in many high profile international courses. In Europe, these include the Echotrainer courses at St Georges in London, the postgraduate cardiac ultrasound course at the European Society of Intensive Care and the echocardiography courses at the European Society of Anesthesia. All have been credited with high participant satisfaction scores. Similarly in the USA, the HeartWorks system is utilized in both TEE and TTE hands-on courses run by the American Society of Echocardiography (ASE) and American Society of Anesthesiologists (ASA). International cardiology societies have also adopted echocardiography simulators as part of their teaching programs.

What do the trainees themselves want? The incorporation of a TEE simulation-based teaching session into a cardiothoracic anesthesia rotation curriculum was strongly endorsed by senior anesthesia residents.

New Developments

I have previously discussed the two types of simulation: group scenarios with an emphasis on human factors and technical simulation to improve dexterity. The new HeartWorks TTE mobile echocardiography simulator allows the integration of the two modes. This has the same features as the standard HeartWorks equip-

ment other than a 'haptic skin' which can fit over any mannequin within a clinical scenario. This opens up a number of exciting possibilities for the development of echocardiography simulation – with the emphasis on putting echocardiography at the centre of hemodynamic crisis management. Further work is needed to translate this into real world outcomes.

The worldwide demand for physician delivered echocardiography competence is increasing. Training programs however have expanding content and contracting timeframes. Echocardiography simulation is now firmly established as a valuable component of echocardiography teaching in many medical specialties. There is a solid evidence base to support this, with international experts recommending inclusion into curricula. [medsim](#)

About the Author

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- www.inventivemedical.com
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