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Original Article

# The impact of internet and simulation-based training on transoesophageal echocardiography learning in anaesthetic trainees: a prospective randomised study

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## Summary

With the increasing role of transoesophageal echocardiography in clinical fields other than cardiac surgery, we decided to assess the efficacy of multi-modular echocardiography learning in echo-naïve anaesthetic trainees. Twenty-eight trainees undertook a pre-test to ascertain basic echocardiography knowledge, following which the study subjects were randomly assigned to two groups: learning via traditional methods such as review of guidelines and other literature (non-internet group); and learning via an internet-based echocardiography resource (internet group). After this, subjects in both groups underwent simulation-based echocardiography training. More tests were then conducted after a review of the respective educational resources and simulation sessions. Mean (SD) scores of subjects in the non-internet group were 28 (10)%, 44 (10)% and 63 (5)% in the pre-test, post-intervention test and post-simulation test, respectively, whereas those in the internet group scored 29 (8)%, 59 (10)%, ($p = 0.001$) and 72 (8)%, $p = 0.005$, respectively. The use of internet- and simulation-based learning methods led to a significant improvement in knowledge of transoesophageal echocardiography by anaesthetic trainees. The impact of simulation-based training was greater in the group who did not use the internet-based resource. We conclude that internet- and simulation-based learning methods both improve transoesophageal echocardiography knowledge in echo-naïve anaesthetic trainees.

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Transoesophageal echocardiography (TOE) is an essential diagnostic and monitoring tool in patients undergoing cardiac surgery. The past decade has seen the use of TOE spread beyond the realm of cardiac surgery to areas such as intensive care and the peri-operative management of high-risk non-cardiac surgical patients [1–5]. Transoesophageal echocardiography provides real-time information on cardiac anatomy and pathology, and can be used to guide the implementation and monitoring of therapeutic measures in the peri-operative period [6]. Within the anaesthetic department, the ability to perform and report TOE is a skill that has been predominantly developed by cardiac anaesthetists so far. With the ever-expanding role of TOE in clinical fields other than cardiac surgery, it may seem prudent to encourage anaesthetic trainees to acquire basic TOE skills. Educational initiatives undertaken by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists in North America may result in the provision of 'basic TOE certification' for non-cardiac anaesthetists [7].

Knowledge of cardiac anatomy and a conceptual appreciation of the orientation of the heart within the chest form the essential basis for acquisition of competency in TOE. Consequently, an understanding of the position of the TOE transducer within the oesophagus or stomach will facilitate the ability to develop the conventional echocardiography planes and resulting images. Effective probe manipulation to acquire standard TOE images can be learnt by rote, but a three-dimensional (3D) appreciation of cardiac anatomy will greatly enhance both the learning experience and ultimately the skill of the operator performing the technique.

Real-time intra-operative experience during cardiac surgery is the most common and effective method of learning TOE. However, theatre scheduling, availability of equipment and personnel and time constraints may be impediments that limit learning opportunities. Furthermore, trends to reduce the hours the trainee anaesthetist spends in the operating theatre may prolong the training time required to gain TOE skills [8]. Anaesthetic trainees may need to look beyond traditional 'on the job' training both to enhance and to compress their TOE learning experience.

Both internet-based free-access interactive TOE learning modules and highly advanced TOE simulators using a 3D heart model have been developed. To develop echocardiographic anatomy knowledge, the simulator presents a simultaneous display of a 3D heart model and the corresponding echocardiography image obtained for the transducer position [9].

The primary objective of this study was to identify whether internet-based interactive TOE learning assists anaesthetic trainees with no previous experience of echocardiography to identify the 20 standard TOE views better than traditional methods such as journal articles, textbooks and lecture-based teaching. The secondary objective of the study was to determine if simulation-based TOE training acts as an effective supplement to either method and augments basic TOE view recognition.

## Methods

The local Research and Ethics Committee waived the need for full ethical approval, following which approval from the St George's Hospital NHS Trust Research and Development directorate was obtained. We obtained written informed consent from 28 anaesthetic trainees (specialty training (ST) year 4 to year 6) scheduled to commence their training program at St George's Hospital in August 2012. Trainees with any previous experience of either transoesophageal or transthoracic echocardiography were not studied, thus creating an 'echo-naïve' cohort of subjects (Fig. 1).

An initial test (pre-test) was administered to all 28 trainees on their first day at St George's Hospital. This consisted of 20 video-based multiple-choice questions designed to assess recognition of standard TOE views and normal anatomy; it was put together by an experienced echocardiographer. Abnormal anatomy, pathology and advanced TOE assessment such as Doppler interrogation, pathology quantification and haemodynamic calculations were not assessed. Each correct answer yielded one point and there was no negative marking for incorrect answers.

Following the pre-test, study subjects were randomly assigned using computer-based software to one of the two groups: traditional learning methods (non-internet group); and online learning (internet group). Subjects in the non-internet group were given the American Society of Echocardiography/Society of Cardiovascular Anesthesiologists (ASE/SCA) guidelines for performing a comprehensive intra-operative TOE examination and instructed to read and absorb them [10]. They were also encouraged to use relevant textbooks and other non–computer-based materials. In the event of a subject needing assistance in aspects of TOE not easily understood via these resources, they were encouraged to seek advice from anaesthetic consultants certified in peri-operative TOE who were blinded to all aspects of this study. Subjects in the non-internet group were asked to refrain from using the internet as an additional source of TOE learning.

The subjects in the internet group received a link to an internet-based TOE learning resource (http://pie.med.utoronto.ca/TEE/TEE_content/TEE_standardViews.html) developed by the Peri-operative Interactive Education group of the Department of Anaesthesia at Toronto General Hospital [11]. This is an online free-access TOE learning resource where users can view the 20-standard TOE image planes

 

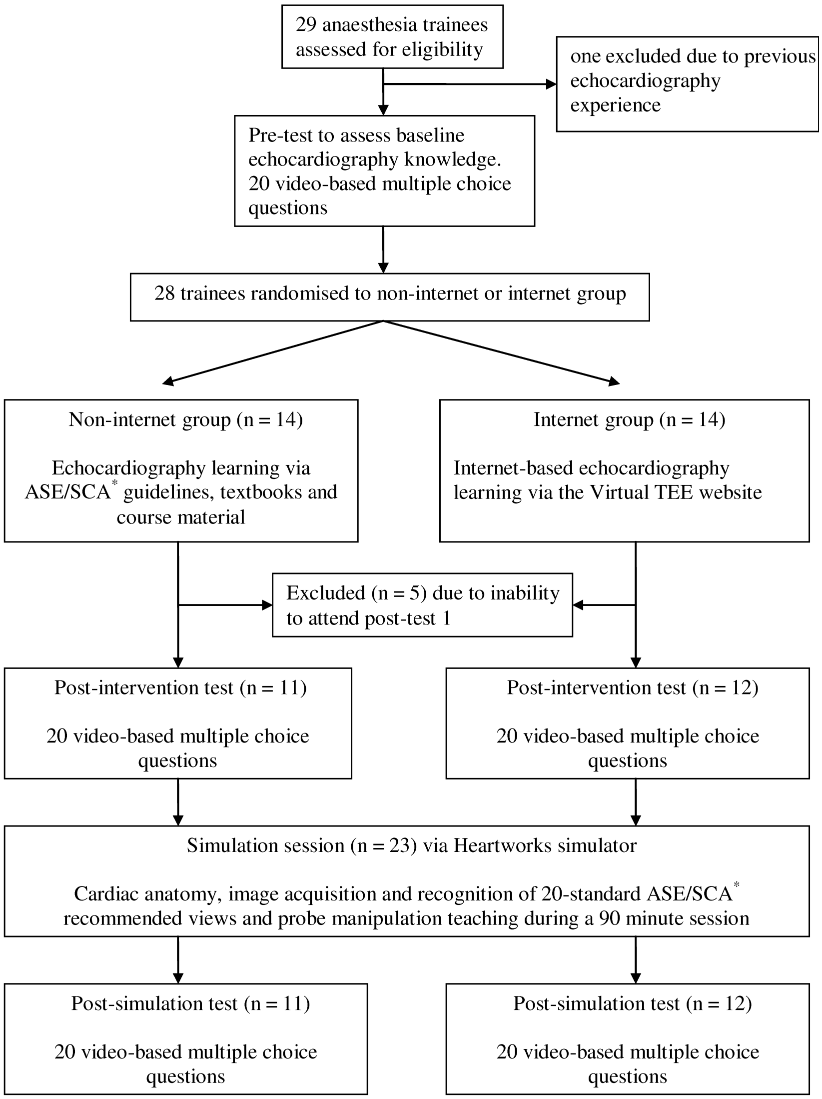


**Figure 1** Study design and method of conduct. *ASE/SCA; American Society of Echocardiography/Society of Cardiovascular Anesthesiologists.

using a steerable 3D heart model that includes an echocardiographic plane and an associated TOE clip [12]. It also allows users to rotate a 3D view of the heart to understand the position of the TOE probe and can 'slice' through it to reveal the internal structures of the heart that correspond to TOE images. Important cardiac structures at each plane are labelled and provided with additional information [11, 12].

Study subjects in both groups were allowed 3 weeks to review the respective educational resources during which they were discouraged from discussing any aspect of the study or exchanging information with their colleagues. A post-intervention test was then administered to all subjects at the end of the 3-week study period. This consisted of 20 different video-based multiple-choice questions, similar in format to the pre-test.

After completion of this test, subjects then attended a 'hands-on' TOE simulation session. The 90-min simulation session was administered by a faculty of experienced echocardiographers blinded to the contents of the tests. The TOE simulator (Heartworks, Inventive Medical Ltd, London, UK) has a computer graphic of a 3D model of the heart with a manikin and dummy probe. It allows the user to slice the 3D view to reveal underlying structures and compare them with the TOE view being obtained in real time. The simulation session began with a demonstration of the acquisition of the 20-standard views as per the ASE/SCA guidelines, and an explanation of the normal anatomy of each echocardiographic plane. Following this, all subjects undertook sequential TOE examinations as per the ASE/SCA guidelines under the supervision of the faculty. Probe manipulation to assist image acquisition and identification of normal anatomy were practised by all subjects in these simulation sessions. The subjects were allowed additional attempts at probe manipulation and image acquisition if required within each simulation session.

Three weeks following the simulation session, the subjects completed a third and final test (post-simulation test) which again asked about normal anatomy and recognition of standard echocardiographic views. This was created by an experienced echocardiographer blinded to the simulation sessions, and different questions were asked from the other two tests. The validity of these video-based multiple-choice questions to discriminate between novice and experienced echocardiographers was assessed by administering the tests to cardiac anaesthetists certified in the use of peri-operative TOE.

Univariate analyses of dichotomous, categorical and continuous variables were carried out, and chi-squared and Fisher's exact tests were used to compare the groups. An independent samples t-test was used to compare the scores within the internet and non-internet groups, and the Mann–Whitney U-test was used to compare test scores of the study subjects and anaesthetic consultants accredited in the use of TOE. The different test results between groups were compared using paired samples t-tests. Statistical analyses were performed using SPSS 19.0 (SPSS Inc, Chicago, IL, USA).

## Results

A total of 28 anaesthetic trainees (23 ST4/5 and five ST6 trainees) undertook the pre-test. Five subjects did not attempt the post-intervention test and were therefore excluded (Fig. 1). There was no difference in baseline knowledge as ascertained by the pre-test between the non-internet and internet groups. There was also no difference in the mean (SD) baseline knowledge between ST4 and ST6 trainees, 30 (9)% vs 31 (10)%, respectively, $p = 0.44$.

Post-intervention test scores were higher than pre-test scores in both study groups, but the increase was greater in the internet group (Table 1). The post-simulation test demonstrated a further increase in the scores of both study groups, and subjects in the internet group continued to outperform those in the control group. However, the increase in the post-simulation test compared with the post-intervention test was significantly greater in the non-internet group (Table 1 and Fig. 2).

Anaesthetic consultants accredited in the use of peri-operative TOE achieved a mean (SD) score of 92 (4)% and 91 (4)% for the post-intervention and post-simulation tests, respectively. These results were significantly better than the post-simulation test results of both study groups ($p < 0.001$).

## Discussion

The results of our prospective randomised study show that the anaesthetic trainees who learnt TOE via an internet-based, interactive resource acquired better image recognition skills than those who utilised traditional learning methods. Simulation training was an effective supplement to both traditional and internet-based learning. Subjects learning TOE via traditional methods appeared to gain more benefit from the simulation session than those who undertook internet-based learning. Despite the beneficial effect of simulation in both groups, the subjects in the internet-based learning group outperformed their counterparts in the traditional learning group throughout the study.

**Table 1** Scores attained by echo-naïve trainees at initial testing (pre-test) and in two subsequent tests (post-intervention and post-simulation). Values are mean (SD).

| | Non-internet group (n = 11) | Internet group (n = 12) | p value |
|---|---|---|---|
| Pre-test; % | 28 (10) | 29 (8) | 0.81 |
| Post-intervention test; % | 44 (10) | 59 (10) | 0.001 |
| Post-simulation test; % | 63 (5) | 72 (8) | 0.005 |

 

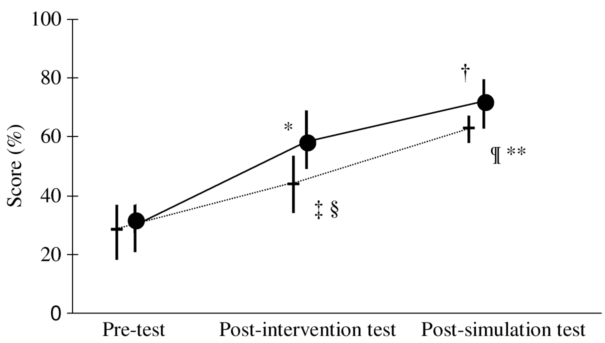


**Figure 2** Mean test scores in the non-internet (–, dotted line) and internet (●, solid line) group. Error bars are SD. *p = 0.001 for post-intervention test scores between groups; †p = 0.005 for post-simulation test scores between groups; ‡p = 0.003 for increase in post-intervention test scores within the non-internet group; §p = 0.00002 for increase in post-intervention test scores within the internet group; ¶p = 0.00002 for further increase in post-simulation test scores within the non-internet group; **p = 0.003 for further increase in post-simulation test scores within the internet group.

Training in TOE in the UK has, up to now, generally been confined to a cardiac anaesthesia fellowship or advanced training program, with intra-operative TOE teaching and experience as the gold standard. To avail the full benefit of intra-operative 'hands-on' TOE learning time, trainees need to acquire a conceptual framework to facilitate the acquisition of the necessary knowledge and skills. This has most commonly been achieved by the use of traditional methods of learning TOE, which include reviewing relevant guidelines, textbooks, course material and tutorials. The introduction of an internet-based, free-access, interactive TOE module has added a new paradigm to TOE teaching [11]. We found that trainees using the internet-based resource acquired a superior understanding of TOE anatomy than those using traditional methods. This may be attributed to the fact that the internet-based resource allows the trainee to view the heart in 3D and learn anatomy and image acquisition in an interactive format, whereas the traditional methods rely on the trainee's ability to conceptualise the heart as a 3D structure and interpret the corresponding 2D echocardiographic planes.

The importance of simulation in various aspects of education has been well recognised and validated in the literature [13, 14]. Simulation in TOE is a relatively new concept and has not been extensively studied [7, 9, 15, 16]. The British Cardiovascular Society working group has recommended simulation-based teaching matched by knowledge acquisition for trainees learning TOE [17]. There are several advantages of simulation-based learning in TOE. It integrates a 3D heart model with all the relevant anatomy and allows corresponding 2D echocardiography image acquisition in real time by manipulating a probe in a manikin. It may also overcome several potential confounding factors that could impede effective echocardiography learning such as time constraints in the operating room and the use of diathermy during image acquisition, and also provides a stress-free environment for image acquisition, interpretation and discussion. Furthermore, simulation training is independent of administrative barriers such as theatre scheduling and cancellations.

This study highlights the benefit of newer methods of learning TOE in an echo-naïve cohort of anaesthetic trainees. Whether simulation technology for learning TOE is cost-effective has not yet been determined and may depend on trainee throughput. We have hence used simulation training as a supplement rather than a replacement for less costly and more easily available resources such as internet-based learning modules. None of the trainees in this study had access to hands-on TOE training such as real-time probe manipulation and image acquisition in the operating theatres for the duration of this study.

There are some limitations to our study. Although larger than previous TOE training studies, our sample size is still relatively small; this may limit the generalisation of these results to a larger population. Due to the voluntary nature of participation and the need to adhere to a time schedule for the administration of the tests, five subjects were not studied as, despite reminders, they failed to attempt the second test. In addition, we did not conduct the tests immediately after the use of the respective educational resources for two reasons. First, we considered that this could lead to overestimation of retention ability. Second, we considered that simulation training may have complemented the internet-based learning resource as they both incorporate a 3D heart model, and so to reduce this potential bias we allowed a 3-week interval between the simulation session and the post-simulation test. The subjects were asked to attempt this test with minimal notice, to eliminate the possibility of revision on their part. It is possible that the subjects in the non-internet group could have gained access to the internet-based learning resource; however, all subjects were specifically questioned on this point at the time of the post-simulation test and all study subjects denied accessing any TOE internet resource. This study was only set up to evaluate the effect of this multi-modular learning on short-term retention of knowledge, and further investigation would be required to ascertain the effects of these methods on longer term acquisition of competence. Finally, we found a statistically significant difference in the test results for anaesthetists already accredited in the use of peri-operative TOE and also in the final post-simulation test results of subjects in both groups. This implies that, although a multi-modular learning process significantly enhances the ability of anaesthesia trainees to understand basic echocardiographic anatomy and image recognition, repeated reinforcement of this learning process and further training in the intra-operative milieu is required to achieve an advanced level of competency.

Jerath and colleagues showed a significant improvement in the ability of trainees to identify cardiac anatomy following review of the same internet-based resource used in our study over a 3-day period [12]. In their study of 10 subjects, trainees achieved a mean (SD) baseline score of 51 (14)%, and after the intervention scored 82 (15)%, both of which are higher than the corresponding scores in our study. In fact, the subjects in our study did not achieve similar high scores at any point during the test schedule. However, the cohort of trainees in Jerath's study comprised anaesthesia, cardiac surgery and cardiology fellows who had already completed general training in their chosen specialty and who may have had greater baseline knowledge of cardiac anatomy. They may also have had a greater vocational commitment to learning TOE than our cohort of anaesthesia trainees with varied sub-speciality interest. Secondly, the second test in Jerath et al.'s study was administered immediately after 3 days of studying the website, as opposed to 3 weeks later in our study.

Bose and colleagues in their prospective randomised study on 14 junior anaesthetic trainees demonstrated a significant benefit of simulation-based TOE training compared with conventional methods [7]. The baseline scores of the anaesthetic trainees in their study were similar to the ones achieved by our cohort. They also showed a statistically significant increase in test scores of trainees randomly assigned to the simulation group. In another study, Cowie and Kluger showed that 2 hours of didactic hands-on transthoracic echocardiography training improved the ability of echo-novice anaesthetic trainees to estimate the severity of aortic stenosis [18].

We conclude that an internet-based TOE learning resource improves understanding and teaching of TOE basic views and cardiac anatomy compared with traditional methods, and that simulation-based learning is as an effective supplement to both methods. The results of this study have encouraged us to introduce internet- and simulation-based echocardiography training as an essential component of our cardiac anaesthesia training module. Larger studies on simulation-based TOE training are required to assess its longer term complementary value in cardiac anaesthesia education programs.

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Dr Fletcher is the director of the St George's Academy of Intra-operative and Intensive Care Echocardiography (a non-profit training initiative) which uses echocardiography simulation as one of a number of teaching techniques. Inventive Medical have provided some free simulators for courses at St George's Hospital. Dr Meineri is a member of the Perioperative Interactive Education group based at Toronto General Hospital, Toronto, Canada.

## Competing interests

No external funding and no other competing interests declared.

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