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A novel multimedia workshop on portable cardiac critical care ultrasonography: a practical option for the busy intensivist

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SUMMARY

We aimed to assess the role of a short duration multimedia workshop to improve the knowledge and skills in cardiac critical care ultrasonography. Thirty critical care physicians participated in the cardiac critical care ultrasonography workshop. Two weeks prior to hands-on training, a three-hour web-based didactic lecture was provided to learners. Hands-on training consisted of a two-hour examination on models without pathology and a 30-minute debriefing with instructors. Pre- and post-workshop knowledge tests were conducted online using 30 multiple choice questions. Pre- and post-workshop skill tests were video captured for evaluation by two reviewers to whom data were masked. Scores were based on 34 predetermined checklist items including learner performance, instrumentation and adequacy of ultrasound images. Learners' confidence levels on image acquisition were assessed using a ten-point Likert scale. A short duration multimedia, hands-on workshop improved intensivists' knowledge, skills and confidence levels on cardiac critical care ultrasonography image acquisition. Further studies are needed to assess the sustainability of observed improvements. This module may be a practical option for the acquisition and maintenance of cardiac critical care ultrasonography knowledge and skills.

Key Words: critical care medicine, ultrasonography, education, computer simulation

The field of point of care ultrasonography has grown exponentially in critical care medicine and is often referred to as critical care ultrasonography (CCUS)[1,2]. Among the four components of CCUS (vascular, thoracic, abdominal and cardiac), cardiac CCUS or critical care echocardiography is one of the most helpful tools to empower intensivists' physical examination skills in the care of critically ill patients.

Several studies on cardiac CCUS have shown that physicians can successfully perform and interpret cardiac CCUS with a short, structured training program[3-8]. However, barriers still exist in the development of a standardised cardiac CCUS education curriculum, mainly because of inflexible schedules of trainees and practising physicians, lack of proficient faculty and duration of training necessary to reach proficiency and ensure patient safety[9,10].

In order to overcome this lack of time, opportunity and resources, we have created a novel educational workshop targeted at novice learners, consisting of web-based didactic learning followed by a hands-on session in a simulation centre. We hypothesised that our multimedia approach and hands-on training would significantly improve basic knowledge and skills necessary for cardiac CCUS. We aimed to report the efficacy of the program by measuring participants' knowledge, technical skills and confidence levels before and after the workshop.

MATERIALS AND METHODS

The study was conducted in an academic teaching hospital in 2010. We developed an innovative multimedia workshop on cardiac CCUS for novice learners. The expected endpoint of the workshop was participant acquirement of basic cardiac CCUS knowledge and skills outlined in the American College of Chest Physicians/La Société de Réanimation de Langue Française competency statement[2]. We administered knowledge and skill

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tests before and after the educational workshop and conducted a survey on the learners' subjective confidence levels. Data were collected prospectively from physicians who participated in the workshop. The Institutional Review Board approved the study (Project No. 09-004867) with a requirement for oral consent from the participants. A total of 30 physicians (seven critical care attending physicians and 23 critical care medicine fellows) participated in the workshop. Two cardiologists took the same knowledge and skill tests without undergoing the workshop in order to ensure the adequacy of the pre and post-workshop test contents.

Participants were first asked to take a web-based pre-workshop knowledge test (Online supplement 1). It consisted of 30 multiple-choice questions on basic cardiac CCUS and image interpretation (seven for anatomy, eight for left or right ventricular function, four for haemodynamics and inferior vena cava [IVC] assessment, two for pericardial disease, six for valvular disease and three for ultrasound physics). The participants were also asked to complete a survey about their previous experience with cardiac CCUS in the clinical setting. After the knowledge test, a total of three hours of web-based didactic lectures were provided to the participants. They were instructed to review the web-based lectures as many times as they wished. Lectures covered the following topics: ultrasound physics; ultrasound machine operation; bedside examination preparation; examination techniques in subcostal, parasternal and apical views; assessment in ventricular size and function, pericardial space, valvular function and IVC size; use of colour Doppler; and basic haemodynamic calculations with continuous and/or pulsed wave Doppler use.

Participants were scheduled to undergo a hands-on training session in the simulation centre two weeks after they were granted access to the web-based lectures. Before the actual training, a pre-workshop skill test was conducted after a 30-minute interactive session with instructors. During the scenario-based skill test, the participants were given three tasks to complete, each within five minutes (Online supplement 2). The skill test was video-captured and the acquired ultrasound images were digitally saved for offline evaluation by two blinded reviewers. The skill scores were calculated on the basis of a 34-topic predetermined checklist (Online supplement 3). The checklist included items for evaluating trainee performance and the adequacy of the ultrasound images obtained.

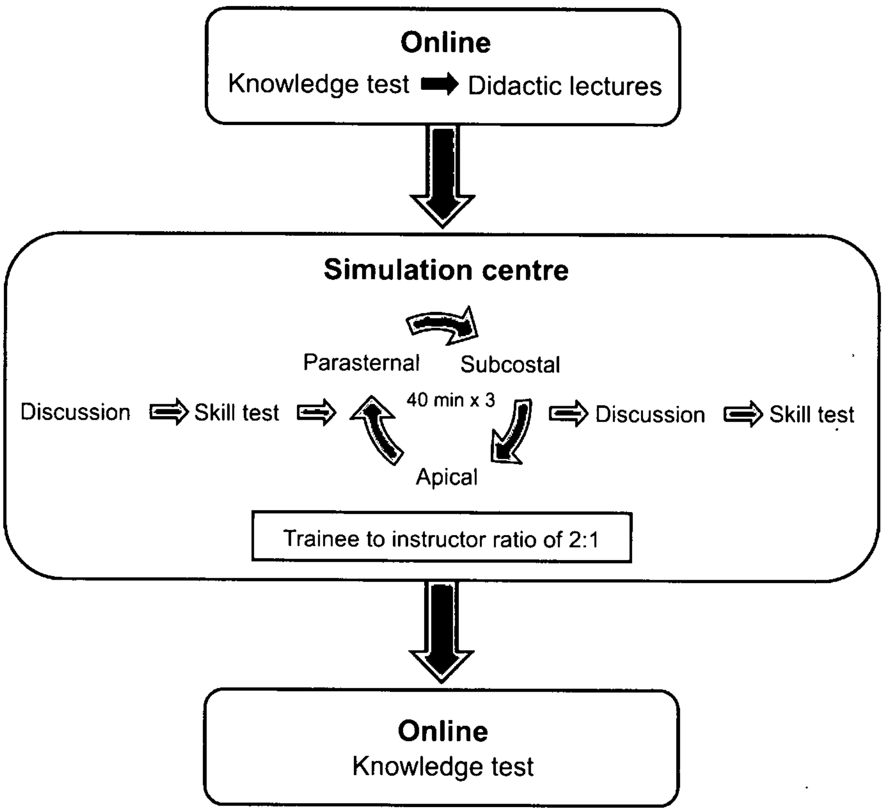

FIGURE 1: Structure of cardiac critical care ultrasonography workshop.

After the pre-workshop skill test, two-hour hands-on training was conducted in the three stations. In order to maximise the hands-on experience, the trainee to instructor ratio was kept at 2:1. Each station had a specific objective for training and the participants rotated among three stations every 40 minutes (Figure 1). The first station mainly focused on the subcostal four chamber and IVC views, the second station on the parasternal long and short-axis views and the third station on the apical four and five chamber views. The instructor at each station taught these core examination techniques first until the learners were deemed comfortable with acquiring the appropriate images independently. If time allowed, instructors also taught more advanced imaging views, such as right ventricular inflow or apical two and three chamber views and the use of Doppler. A portable heart anatomy model was used at each station to enhance learners' understanding of the ultrasound transducer orientation. Examples of normal and abnormal images were reviewed during the session depending on the educational need of the trainee. A portable ultrasound machine (MicroMaxx, SonoSite, Inc., Bothell, Washington, USA) with a phased array transducer (P17 transducer) was used in each station.

After the hands-on training, a 30-minute session of debriefing and interactive discussion was performed. The participants received additional feedback, such as machine operation and image acquisition techniques, in this session. After the session, a post-workshop skill test was administered. The content and the level of difficulty were the same as in the pre-workshop skill test. After the post-workshop skill test, the participants were asked to complete the survey to report their confidence levels for image acquisition before and after training by using a ten-point Likert scale. They were also asked to provide feedback on the workshop anonymously. Finally, participants were asked to complete a web-based post-workshop knowledge test within two weeks of their completion of the hands-on training in the simulation centre.

Two cardiologists (American College of Cardiology Level 3) underwent both knowledge and skill tests. Neither of them received web-based training or hands-on training. Their performance scores were used for comparison with those of novice learners to ensure the adequacy of the test contents.

We prospectively constructed a database of participants' levels of postgraduate training, previous experience in cardiac CCUS, scores of pre and post-workshop tests and subjective confidence levels for ultrasound image acquisition. Quantitative parameters were expressed as mean (standard deviation [SD]). For the skill portion of the tests, a Bland-Altman plot was used to analyse agreement between

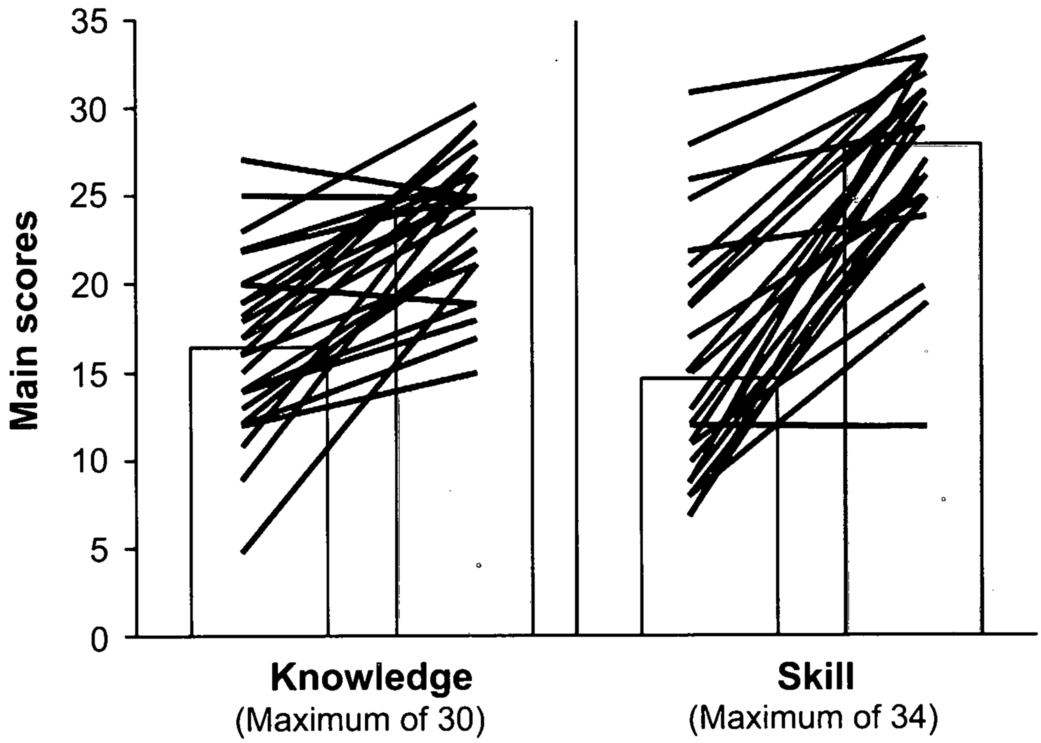

FIGURE 2: Knowledge and skill test scores. Mean post-workshop knowledge and skill scores (black bars) increased significantly from mean pre-workshop scores (white bars). P <0.001 for all.

the two reviewers. Learners' confidence levels for image acquisition were assessed with a ten-point Likert scale. Changes in the knowledge and skill test scores through the workshop were evaluated using a paired t-test. Wilcoxon signed-rank test was used to compare changes from pre to post-workshop confidence levels. All computations were performed by JMP 9.0 (SAS Institute Inc., Cary, North Carolina, USA) on data imported from a Microsoft Excel 2007 spreadsheet (Microsoft Corp, Redmond, Washington, USA). To account for multiple testing, each of the tests was run at a significance level of 0.05 divided by three; a *P* value of less than 0.017 was considered statistically significant.

RESULTS

Thirty critical care physicians participated in the cardiac CCUS workshop. Twenty-seven learners had performed ten or fewer cardiac CCUS examinations prior to the workshop. One learner had performed more than 50 examinations and two learners had performed 21–49 examinations.

The mean (SD) pre and post-workshop knowledge and image interpretation scores were 16.4 (4.9) and 24.2 (3.8), out of a maximum of 30 (P <0.001) (Figure 2). The percentage of correct answers improved in each question category from 51–81% in anatomy, 48–70% in ventricular function, 58–90% in haemodynamics and IVC, 57–77% in pericardial disease, 59–87% in valvular disease and 51–64% in physics.

The skill test had three types of view window components: subcostal (13 scores), parasternal (12 scores) and apical (nine scores). The mean (SD) pre and post-workshop scores were 14.7 (6.6) and 28.0 (4.9) (maximum score, 34) (P <0.001) (Figure 2). The percentage of correct answers increased from 36–80% in the subcostal section, 48–83% in the parasternal section and 48–83% in the apical section. A Bland-Altman plot demonstrated that the scores of the two reviewers were consistent and similar (Figure 3).

The median score (25–75 percentile) of the subjective confidence levels increased from 1.0 (1.0–2.3) to 7.0 (6.0–8.0) after the workshop (P <0.001). A significant correlation existed between the pre-workshop subjective confidence levels for image acquisition and the pre-workshop skill test cores (correlation, 0.12; 95% confidence interval, 0.02–0.21; P=0.01). However, no such correlation was seen in the post-workshop period (P=0.81).

The two cardiologists who had not participated in either web-based lectures or hands-on training both scored 30 out of 30 in the knowledge test and scored 33 and 34 out of 34 in the skill test.

DISCUSSION

Our novel multimedia educational workshop significantly improved physicians' scores in knowledge and technical skill sets in cardiac CCUS, along with subjective confidence levels for image acquisition. Importantly, training and evaluation occurred within

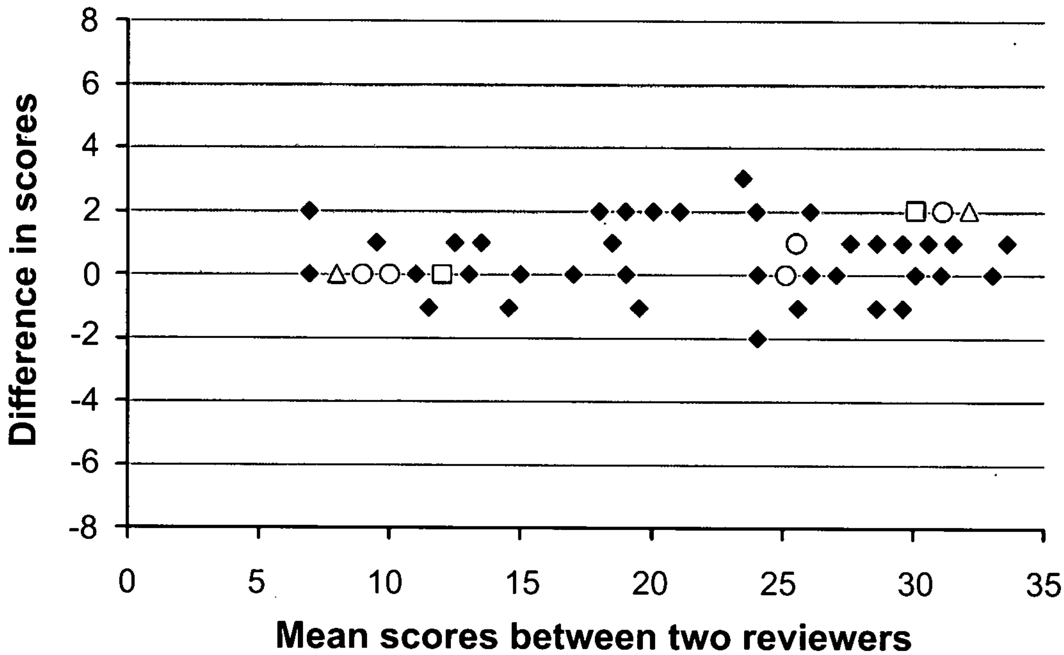

FIGURE 3: A Bland-Altman plot of the scores of two skill test reviewers. The plot shows that the skill test scores of the two reviewers were consistent and similar. Black diamonds represent a single unique score. Circles, squares and triangles represent two, three and four individual scores respectively.

the work schedule of attending physicians and critical care fellows.

Most studies of cardiac CCUS education are from emergency medicine. Randazzo et al described that an experienced emergency medicine physician trained in sonography can accurately assess left ventricular function and IVC size[5]. Jones et al developed an echocardiography workshop consisting of five hours of didactic lectures and one hour of hands-on training to evaluate the knowledge and skill improvement of emergency medicine residents[3]. Although the study demonstrated a significant improvement of scores in knowledge and skill tests, nine of the 30 residents were not able to complete didactic lectures because of their busy schedules and were excluded from the analysis. Vignon et al also reported their echocardiography training of four to six non-cardiology residents in France and demonstrated a reasonable accuracy of residents' impressions compared with the impressions of experienced attending physicians[7,8]. A study group from Turkey recently reported its training curriculum and the accuracy of diastolic function assessed by emergency physicians[6].

Reports on cardiac CCUS education are emerging in the field of critical care medicine. Melamed et al conducted an educational course consisting of two hours of didactic instruction and four hours of hands-on sessions for four intensivists[4]. The intensivists evaluated the patients' left ventricular function into the three categories: normal, mild to moderately decreased, and severely decreased. The authors concluded that intensivists were able to estimate left ventricular function with reasonable accuracy after undergoing minimal training. Royse et al reported results of a structured training program including both knowledge and practical skill acquisition[11]. Their training program included pre-course tutorials (around 40 hours of reading) and tutorials at a workshop running parallel to the hands-on practice[11]. Although the study did not assess the learners' image acquisition skills, it demonstrated that learners correctly interpreted limited echocardiography with relatively high accuracy[11].

Compared with these previous reports on cardiac CCUS education, our workshop has several unique points. First, it has a web-based approach that could be completed or repeated independently over a two-week period prior to hands-on training with models and without pathology in a simulation centre. As many as 30 critical care attending physicians and fellows were able to complete our workshop despite their busy schedules. The integration of multimedia or web-based training methods into ultrasonography education has been suggested by several authors[1,9,11], and it has been widely and effectively used in training for ultrasound-guided central venous catheter insertion[12-15]. The novelty of our study included systematic evaluation of the effectiveness of a web-based multimedia workshop on cardiac CCUS from both knowledge and skills perspectives.

Second, our study has a curriculum tailored for the care of critically ill patients in the intensive care unit. We created a structured workshop that covered the requirements for competency in cardiac CCUS outlined in the recent American College of Chest Physicians/La Société de Réanimation de Langue Française competency statement[2]. We collaborated with echocardiography-certified cardiologists to create an organised and comprehensive web-based curriculum that involved archives of normal and abnormal images. Team collaboration enhanced the quality of the educational content while limiting the total educational time to five and a half hours (three hours web-based learning, two hours hands-on training and a 30-minute debriefing session).

Previous reports identified barriers to the development of standardised CCUS curricula, such as inflexible schedules of trainees and practising physicians, lack of proficient faculty and the extensive training necessary to reach proficiency and ensure patient safety[9,10]. We believe that our multimedia training structure can potentially eliminate some of these barriers. First, participating physicians had access to the online learning materials and archives of ultrasound images at any time they wished. This access allowed learners to have flexibility of scheduling lectures when they were most receptive to learning. In addition, they could repeat lectures or components of lectures if they felt it was necessary for obtaining core knowledge. Second, our web-based didactic lectures were practical for instructors whose schedules were not flexible. The module enables a minimum number of instructors to train a large number of learners in ultrasound physics, basic examination techniques and image interpretation. This approach may alleviate the current lack of proficient faculty in this relatively new, and growing, field.

The scores from the pre-workshop skills test were relatively lower than expected despite the detailed video demonstrations on machine control and image acquisition. This finding may indicate that web-based learning alone may not be enough to attain proficiency at CCUS image acquisition. Proper CCUS acquisition relies on appropriate patient positioning and detailed machine operation as well as hand–eye–brain coordination to adjust the angulations or rotation of the transducer. We believe that hands-on training under the direct supervision of faculty is crucial in the improvement of learners' CCUS performance. Interestingly, subjective confidence levels on image acquisition significantly correlated with pre-workshop skill test scores but not with post-workshop skill test scores. The post-workshop scores were high and similar among the majority of learners with a relatively small SD. This result potentially indicates that our workshop was successful in bringing learners with various initial confidence levels to a basic level of competence.

Our project has a few limitations. First, we aimed to measure the short-term improvement in the basic level of cardiac CCUS performance after the workshop. Long-term follow-up must be assessed to evaluate retention of the knowledge and skill set acquired. Second, although two cardiologists attained close to 100% correct answers in both knowledge and skill tests, the content of the knowledge test and the checklist items of the skill test need to be constructively validated. Third, the models in the hands-on training session had only normal findings and the learners were not trained to acquire images on patients with difficult ultrasonographic windows or to interpret abnormal findings at the bedside. We believe that this learning process must happen during actual patient care at the bedside and under the supervision of CCUS experts, with the understanding that CCUS is a screening tool to enhance the physical examination and not a definitive diagnostic modality. Our study was not designed to assess the bedside CCUS competency in a clinical practice environment or the clinical utility of the ultrasonographic skills. We recognise that application of cardiac CCUS is a highly complex skill. We hope our unique training program allowed participants to achieve basic competency in image acquisition, and will be a building block for future CCUS skill development.

CONCLUSION

We showed that a workshop consisting of web-based learning combined with hands-on training significantly improved novice learners' knowledge, technical skills and subjective confidence levels on cardiac CCUS. We believe that our multimedia module is reproducible and provides a system to allow novice learners to achieve basic levels of CCUS competence. Our flexible web-based module can also be a practical option for busy critical care practitioners to maintain the knowledge and skill set of cardiac CCUS.

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