Simulation-Based Echocardiography Teaching in Medical Education: A Test-Based Pilot Study

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Abstract: Echocardiography is fundamental to diagnostic medicine, yet medical students seldom learn it. Simulation-based training to improve echocardiography learning is promising. This study examined how simulation-based echocardiography training affects final-year medical students’ knowledge and abilities. The study involved 16 medical students. Prior ultrasound experience and self-assessed competence were assessed using a pre-test that also had six multiple-choice questions on cardiac anatomy and physiology. The students went through an echocardiography teaching session using a simulator and a post-test with similar questions as the pre-test was administered thereafter. We compared both tests, and data analysis was performed using Microsoft Excel. Most students had little echocardiography experience before the class. After the teaching, scores averaged 5.07, up from 4.13 in the pre-test. Differences in pre-test and post-test scores were statistically significant (p = 0.007). The responses represented an improvement in self-assessed competence after the session. Simulation-based echocardiography improved medical students’ knowledge and skills. This study emphasizes the need for simulation-based training research to determine its long-term effects on clinical practice.

Keywords: echocardiography; simulation-based teaching; medical education; ultrasound simulation

1. Introduction

The significance of ultrasonography in diagnostic medicine cannot be ignored, along with its importance to the health practitioner. Nevertheless, most medical students do not receive sufficient exposure to echocardiography while in medical school [1]. A potential way of increasing the ability of students to learn and practice their skills is through the use of simulations, especially in echocardiography, which has become increasingly popular. Simulation is a method of teaching that replaces actual patient interactions with virtual patients, live actors, or artificial models [2,3].

Simulation-based echocardiography instruction helps students gain the skills and confidence needed to conduct echocardiograms reliably and successfully in clinical practice [4]. This study examined how simulation-based echocardiography instruction affects final-year medical students’ knowledge and skills.

2. Materials and Methods

This was a prospective study that involved 16 University of Glasgow final-year medical students undertaking their cardiology block. They were randomly placed into groups of eight, and the first two groups were selected. A pre-test was administered to the students, consisting of self-assessment on ultrasound experience and competence as well as six multiple-choice questions on cardiac anatomy and physiology (see Appendix A). The students had 10 min to complete the assessment.

Subsequently, a simulation-based echocardiography teaching session was administered using the HeartWorks (Medaphor Medicentre, Cardiff, UK) ultrasound mannikin...
simulation package. The teaching involved two small groups of eight each on two separate days, and the method was a combination of didactic and practical components, with each student taking turns to practice on the simulator. During these sessions, students practice how to hold the probe, understand the various views, identify the cardiac walls and chambers, and also identify normal heart physiology while correctly identifying pathology on the simulator. Both sessions lasted between 90 and 120 min each.

A post-test was administered after each teaching intervention to reassess ultrasound competence and included the same knowledge questions as the pre-test (see Appendix B). This also lasted 10 min. The results of the pre-test served as a baseline for comparison with the post-test. The questions were set by a teaching fellow separate from the instructor, and anatomy and physiology questions were randomly selected that were linked to echocardiography learning. This study was carried out as a component of normal academic activities, with the students taking part voluntarily.

The variables were analyzed using Microsoft Excel (version 2010) with the use of mean, percentages, and standard deviation. A statistical significance level of <0.05 was used for two-tailed \( p \)-values.

3. Results

The majority of the students, 15 (93.8%), stated that they had observed but not practiced echocardiograms prior to the teaching session. On the other hand, one student (6.2%) had practiced echocardiography prior to the session. This was determined by the assessment of prior ultrasonography knowledge and self-assessed competency. Only one student, or 6.2%, reported feeling comfortable when using an echocardiography device, whereas five students, or 31.3%, reported feeling slightly uncomfortable, and ten students, or 62.5%, reported feeling very uncomfortable when using the device.

Pre-test scores on the multiple-choice questions averaged 4.13, with a standard deviation of 0.74 (see Table 1). The mean score on the post-test was 5.07, with a standard deviation of 0.96, which indicates that there was an improvement following the instruction session. The question most frequently answered incorrectly was “in which cardiac cycle phase do the atrioventricular valves open?” It was determined that there was a difference between the two sets of tests that was statistically significant (\( p = 0.007 \)). In response to the question of whether or not they had improved their competence, 12 individuals (75%) claimed that they had improved their own competence, while 3 individuals (18.8%) said that they had significantly improved.

<table>
<thead>
<tr>
<th>Table 1. Mean test scores.</th>
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<td>Pre-Test</td>
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<td>4.13 ± 0.74</td>
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4. Discussion

This study indicates that simulation-based echocardiography teaching has a positive impact on knowledge and skill acquisition in medical education. Despite the pre-test revealing that the majority of students had limited practical experience with echocardiography, the post-test showed a statistically significant improvement in test scores and encouraging self-assessed competence. This is similar to the results from a study which showed that simulation-based echocardiography teaching enhanced exam performance, reduced the duration of exams, and increased contentment amongst medical students [5].

For medical students studying echocardiography, simulation-based instruction offers a number of benefits over conventional approaches [6]. Medical students’ acquisition of information and skills has been demonstrated to be improved by it. In one study, students were shown to increase their scanning skills and their interpretation skills somewhat [7]. A similar study emphasized the effect of simulation-based training on converting knowledge into improved technical abilities [8]. What these findings demonstrate is that medical
students’ learning of echocardiography skills is enhanced by simulation-based instruction. Furthermore, theoretical and practical information may be integrated into teaching through simulation. Through practical applications of the theoretical ideas they have studied in lectures or textbooks, students would better assimilate and remember the content.

It has been established that echocardiography is a viable and efficient way to increase medical students’ cardiac anatomy and physiology understanding [9,10]. In this study, cardiac anatomy and physiology knowledge improvement after the teaching session was used as an indirect assessment of the impact of echocardiography amongst medical students. Furthermore, the reverse also applies as optimal cardiac anatomy and physiology knowledge aids efficient scanning. The European Association for Echocardiography recommends a comprehensive understanding of the structure and functional abnormalities of the cardiovascular system in an echocardiography training curriculum [11].

In a world of increasing litigation in the healthcare space, simulation-based training presents a unique soft landing. It is becoming less and less acceptable to learn challenging and error-prone activities by making mistakes on actual patients [12]. When compared to more conventional teaching approaches, which allow students to practice on actual patients, simulation-based learning lowers the level of danger to both patients and learners. It offers trainees a regulated and secure setting in which to hone their echocardiography techniques. Additionally, in contrast to patients or human actors, simulators have an edge of constant availability [13].

Students can also experience a variety of clinical settings and pathologies using simulation-based echocardiography [4]. This diversity of scenarios helps students comprehend echocardiography and prepares them for clinical practice, where they may face individuals with varied heart problems. Regular ultrasound practice may also help retain and improve abilities [14]. Whether this ultimately leads to a tangible improvement in clinical outcomes is still a largely unexplored area [12].

Simulation-based transthoracic echocardiography teaching promotes recurring practice that allows students to consolidate their knowledge and enhance their technical echocardiography skills. It also enables immediate feedback from trainers upon mistakes or misconceptions, encouraging the identification and correction of such flaws right away [15]. This kind of personalized tutoring support is uncommon in conventional teaching methods. Students will not receive this type of personalized feedback and guidance in traditional methods of teaching since they receive feedback on their clinical encounters weeks or even months later [16].

The indication of improvement in competence in this study is likely to be related to the wide acceptance of the simulation model of training. Unsurprisingly, the feedback received from students at the end of their cardiology block consistently indicates a significant impact of echocardiography-simulated learning on their learning experience. In a study performed to analyze medical students’ assessment of valvular heart disease, the authors noted that the students reported profound satisfaction and that their ultrasound experience greatly enhanced their medical education [17].

Despite the obvious benefits of simulation in medical education, its availability and deployment still vary across regions. Gaps created by resource and technical limitations have affected its availability and acceptability [18]. This ultimately results in a slow adoption of innovations in medical education until a national consensus is reached among medical leaders [19]. This suggests that the integration of simulation-based teaching methods, such as the use of ultrasound simulators, may require a shift in the medical education paradigm.

The limitations of this study include the small sample size, the lack of control measures between both set of tests, the use of a single center, and the collection of data within a short period of time. However, this study has provided excellent pilot material on which to build future projects in both undergraduate and postgraduate courses.

The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.
5. Conclusions

Teaching echocardiography based on simulation has resulted in students acquiring an increased amount of skills and knowledge. The literature shows that the continued use of simulated teaching models is considered important for medicine teaching and has exciting prospects. Further research in this area is essential to explore the long-term impact of simulation-based teaching and its implications for clinical practice.

Simulation-based echocardiography teaching has the potential to enhance medical education and improve the proficiency of medical students in echocardiography, ultimately contributing to better patient care and outcomes.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Pre-test
Prior echocardiography experience
I have seen an echocardiography performed before, but not practiced [ ]
I have practiced echocardiography less than five times [ ]
I have practiced echocardiography five times or more [ ]
I have not seen an echocardiography performed [ ]

Self-Assessed Competence
How comfortable are you with using an echocardiography device?
Very uncomfortable [ ]
Somewhat uncomfortable [ ]
Comfortable [ ]
Somewhat comfortable [ ]
Very comfortable [ ]

Multiple-choice questions
Which cardiac chamber is the most anterior?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]

Which cardiac chamber is the largest?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]
Which cardiac chamber has the thickest wall?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]

The atrioventricular valves open during?
Systole [ ]
Pre-systole [ ]
Diastole [ ]
Early Diastole [ ]

Which cardiac phase represents ventricular filling?
Systole [ ]
Pre-systole [ ]
Diastole [ ]
Early Diastole [ ]

A 52-year-old hypertensive has a resting heart rate of 100 beats per minute and a stroke volume of 50 mL. What is his cardiac output?
5500 mL [ ]
100 mL [ ]
5000 mL [ ]
5100 mL [ ]

Appendix B
Post-test
Multiple-choice questions
Which cardiac chamber is the most anterior?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]

Which cardiac chamber is the largest?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]

Which cardiac chamber has the thickest wall?
Right ventricle [ ]
Left atrium [ ]
Left ventricle [ ]
Right atrium [ ]

The atrioventricular valves open during
Systole [ ]
Pre-systole [ ]
Diastole [ ]
Early Diastole [ ]

Which cardiac phase represents ventricular filling?
Systole [ ]
Pre-systole [ ]
Diastole [ ]
Early Diastole [ ]

A 52-year-old hypertensive has a resting heart rate of 100 beats per minute and a stroke volume of 50 mL. What is his cardiac output?

5500 mL [ ]
100 mL [ ]
5000 mL [ ]
5100 mL [ ]

Self-Assessed Competence
How comfortable are you with using an echocardiogram device after the echocardiography simulation?
Significantly worsened [ ]
Worsened [ ]
No change [ ]
Improved [ ]
Significantly improved [ ]

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