

Comparison of Transthoracic Echocardiography Simulators for Anesthesia Resident Education: Postprint

Authors: Bai Bing, countryside, Li Xu, Yu Chunhua, Huang Yuguang

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Abstract

Objective To investigate the teaching effectiveness of two different TTE simulators in transthoracic echocardiography (TTE) training for anesthesiology residents. **Methods** A total of 63 residents participated in our prospective randomized controlled study. They were randomly divided into 3 groups: experimental group 1 (n=21) using the Heartworks simulator, experimental group 2 (n=21) using the U/S Mentor simulator, and a control group (n=21) receiving traditional teaching format training. The assessment indicators for effectiveness evaluation included written examinations on fundamental knowledge (administered both before and after training) and practical operation assessments on volunteer models after training (image acquisition quality and anatomical structure identification). **Results** There were no statistically significant differences in pre-training fundamental knowledge test scores among the groups. Post-training test results showed no statistically significant difference between experimental group 1 and experimental group 2, but both were superior to the control group. Post-training written examination scores were $53.8\% \pm 12.6\%$ for experimental group 1, $52.6\% \pm 13.6\%$ for experimental group 2, and $43.3\% \pm 10.8\%$ for the control group; $P < 0.0167$. In the practical operation assessment, image acquisition quality scores for the three groups were (17.1 ± 4.5 , 16.0 ± 4.1 , 7.7 ± 3.1 ; $P < 0.0167$) respectively, while anatomical structure identification scores were (18.2 ± 6.3 , 17.0 ± 6.1 , 11.9 ± 6.9 ; $P < 0.0167$) respectively. **Conclusion** In TTE training for anesthesiology residents, there was no statistically significant difference in training effectiveness between the two TTE simulators, but both were superior to traditional lecture-based teaching. Simulator-based teaching can help anesthesiology residents better master TTE-related fundamental knowledge and accomplish practical operations of TTE image acquisition and anatomical structure identification.

Full Text

Comparison of Two Different TTE Simulators in Teaching Transthoracic Echocardiography Skills to Anesthesiology Residents

Bai Bing, Tian Yuan, Li Xu, Yu Chunhua*, Huang Yuguang

Department of Anesthesiology, Peking Union Medical College Hospital, Beijing 100730, China

Corresponding author: Yu Chunhua; Email: yu.chunhua@aliyun.com

Abstract

Objective: To evaluate and compare the effectiveness of two different transthoracic echocardiography (TTE) simulators against traditional teaching methods for anesthesiology residents.

Methods: Sixty-three anesthesiology residents participated in this prospective randomized controlled study and were randomly assigned to three groups: Simulation Group 1 (n=21) using the Heartworks simulator, Simulation Group 2 (n=21) using the U/S Mentor simulator, and a control group (n=21) receiving traditional instruction. Assessment metrics included a written knowledge test (administered both pre- and post-training) and a practical skills examination on volunteer models (evaluating image acquisition quality and anatomical structure identification).

Results: No statistically significant differences were observed in baseline pre-training written test scores among the three groups. Post-training test results showed no difference between the two simulation groups, but both significantly outperformed the control group. Post-training written test scores were $53.8\% \pm 12.6\%$ for Group 1, $52.6\% \pm 13.6\%$ for Group 2, and $43.3\% \pm 10.8\%$ for the control group ($P < 0.0167$). In the practical examination, image acquisition quality scores were 17.1 ± 4.5 , 16.0 ± 4.1 , and 7.7 ± 3.1 respectively ($P < 0.0167$), while anatomical structure identification scores were 18.2 ± 6.3 , 17.0 ± 6.1 , and 11.9 ± 6.9 respectively ($P < 0.0167$).

Conclusion: In TTE training for anesthesiology residents, no significant difference was found between the two simulator types, but both were superior to traditional teaching methods. Simulator-based instruction helps anesthesiologists better master TTE-related theoretical knowledge and practical skills in image acquisition and anatomical structure identification.

Keywords: simulation teaching; transthoracic echocardiography; anesthesiology

Introduction

Growing evidence demonstrates that bedside transthoracic echocardiography (TTE) enables anesthesiologists to rapidly and accurately identify causes of hemodynamic instability during the perioperative period, thereby guiding clinical management. The dynamic, real-time, and non-invasive advantages of cardiac ultrasound have led to increasingly widespread TTE application. As TTE utilization expands across clinical departments, many specialties—particularly anesthesiology, emergency medicine, and critical care—have begun implementing TTE training programs, with some even incorporating TTE instruction into China’s continuously evolving standardized residency training curriculum. Many medical educators believe that traditional TTE teaching models no longer meet the demands of modern medical education. Consequently, the application of TTE simulators in contemporary medical teaching has garnered significant attention in recent years. This study aims to compare the educational effectiveness of two different TTE simulators against conventional lecture-based instruction for teaching TTE fundamentals and practical skills to anesthesiology residents.

1. Methods

This study received ethics committee approval, and informed consent was obtained from all participants. We conducted teaching and assessment sessions with 63 anesthesiology residents in the standardized training program at Peking Union Medical College Hospital. All participants were junior physicians with 1-3 years of clinical anesthesia experience and no prior echocardiography training. We randomly divided these residents into three groups while ensuring consistent distribution of training years across groups: Experimental Group 1 (using the Heartworks simulator, Inventive Medical Ltd, UK; n=21), Experimental Group 2 (using the U/S Mentor simulator, 3D Systems formerly Symbionix, USA; n=21), and a control group (traditional teaching; n=21).

Before training, all residents completed a 45-minute written examination consisting of 20 multiple-choice questions covering TTE imaging principles, indications, basic views and recognition, and clinical applications. The questions were developed by cardiac anesthesia specialists from our department. Following the pre-test, each resident received 45 minutes of standardized training covering TTE imaging principles, indications, standard views (including five basic views assessed in the test), probe manipulation, cardiac anatomy, and volume status assessment. All three groups followed the same curriculum outline. The control group watched instructional videos with live expert Q&A, followed by 15 minutes of one-on-one supervised practice on a volunteer model (other residents could not observe). The simulation groups received 20 minutes of expert instruction using their respective TTE simulators (Heartworks or U/S Mentor) with Q&A, followed by 15 minutes of one-on-one supervised practice on the simulator (other residents could not observe).

After training, residents completed a post-training written test with the same scope as the pre-test, followed by a practical examination on healthy volunteer models. The practical assessment required residents to obtain five fundamental apical and parasternal views within 10 minutes using a GE Vivid S5 ultrasound machine (General Electric, Israel): left ventricular long-axis view (requiring identification of left atrium, left ventricle, right ventricle, aortic valve, mitral valve, ascending aorta, and pericardium), parasternal right ventricular outflow tract view (right atrium, right ventricle, and tricuspid valve), parasternal short-axis view (anterior, inferior, inferolateral, anterolateral, anteroseptal, and inferoseptal walls), apical four-chamber view (left atrium, left ventricle, right ventricle, right atrium, mitral valve, and tricuspid valve), and apical two-chamber view (left atrium, left ventricle, and mitral valve). Cardiac anesthesia specialists evaluated anatomical structure identification without providing guidance during the examination. Trainees acquired what they considered optimal views, froze the images, and then identified anatomical structures on the frozen frames.

Our scoring system involved two cardiac anesthesia specialists who were blinded to group assignments. They scored both image quality and anatomical structure identification. Image quality was scored out of 25 points (0-5 points per view). After obtaining the view, residents identified corresponding cardiac structures, with a total possible score of 25 points for structure identification. If view acquisition exceeded 120 seconds, both structure identification and image quality for that view received zero points. At the conclusion of training and assessment, we administered a satisfaction survey evaluating five aspects: overall satisfaction, learning effectiveness for cardiac structure identification, learning effectiveness for TTE probe manipulation, likelihood to recommend to colleagues, and ease of use. Responses were rated as satisfied, neutral, or dissatisfied.

Statistical Analysis

We performed statistical analysis using SPSS 19.0 software (SPSS, Chicago, IL). Data are presented as mean \pm standard deviation (\pm s). Intergroup comparisons among Experimental Group 1, Experimental Group 2, and the control group were conducted using analysis of variance, Tukey's test, and Kruskal-Wallis test as appropriate.

2. Results

No statistically significant differences were found in pre-training written test scores among the three groups: Group 1 averaged $41.4\% \pm 10.6\%$, Group 2 averaged $40.4\% \pm 10.9\%$, and the control group averaged $39.8\% \pm 10.5\%$. Post-training written test scores showed no difference between the two simulation groups, but both were significantly higher than the control group: Group 1 scored $53.8\% \pm 12.6\%$, Group 2 scored $52.6\% \pm 13.6\%$, and the control group scored $43.3\% \pm 10.8\%$ ($P < 0.0167$).

In the practical examination, image acquisition quality scores were 17.1 ± 4.5

for Group 1 and 16.0 ± 4.1 for Group 2, with no statistical difference between them, but both significantly exceeded the control group' s score of 7.7 ± 3.1 ($P < 0.0167$). Anatomical structure identification scores were 18.2 ± 6.3 for Group 1 and 17.0 ± 6.1 for Group 2, both significantly higher than the control group' s 11.9 ± 6.9 ($P < 0.0167$) .

Regarding teaching satisfaction, no statistically significant differences were observed among the three groups across all five survey aspects: overall satisfaction, cardiac structure identification learning effectiveness, TTE probe manipulation learning effectiveness, likelihood to recommend to colleagues, and ease of use ($P > 0.05$) .

3. Discussion

Transthoracic echocardiography is increasingly utilized in numerous clinical departments including anesthesiology, with studies suggesting that TTE monitoring can significantly improve outcomes in critically ill patients. In clinical practice, when repeated examinations are necessary, TTE serves as an invaluable tool for anesthesiologists. TTE enables timely detection of cardiac structural and functional changes, facilitates volume assessment, allows for early diagnosis, and provides crucial reference information for developing subsequent treatment plans.

Mounting evidence indicates that simulation-based teaching represents the future direction of modern medical education. Our study reaffirms the advantages of simulation over traditional instruction: both TTE simulators significantly improved anesthesiologists' acquisition of TTE knowledge and operational skills compared to conventional teaching. Residents in the simulation groups not only achieved higher post-training written test scores but also demonstrated superior practical performance and structure identification abilities.

Medical educators increasingly recognize that simulation-based teaching overcomes the traditional model' s emphasis on theory at the expense of practice by providing learners with more opportunities for direct observation, interaction, and hands-on experience, which substantially enhances educational outcomes. Furthermore, we observed that despite the relatively short training duration, simulation produced significant improvements in performance, suggesting that simulator-based instruction may represent a promising trend for standardized TTE training in anesthesiology residency programs.

The rise of simulation-based teaching has greatly advanced modern medical education, and the introduction of TTE simulators such as Heartworks and U/S Mentor has drawn considerable attention to their role in medical training. As simulator technology continues to improve, these devices increasingly approximate real clinical patients, while ongoing software enhancements maximize their advantages in intuitiveness and interactivity for TTE instruction. In our study,

TTE simulators enabled residents in both experimental groups to achieve higher written test scores, produce higher-quality images, and more accurately identify anatomical structures, while maintaining satisfaction levels comparable to the traditional teaching group. Previous international studies have demonstrated clear advantages of simulators in TTE training for residents, and our research further validates these findings while filling a gap in the domestic literature.

Our study has several limitations. The practical examinations were conducted on healthy volunteers rather than actual clinical patients. Although we demonstrated the advantages of TTE simulators during entry-level training for nearly “zero-baseline” residents, this represents only an initial step that remains far from achieving clinical proficiency in TTE application. Therefore, further educational research is warranted.

In summary, simulation-based teaching has demonstrated clear advantages in primary TTE training for anesthesiology residents. However, whether simulators can enable anesthesiologists to apply TTE in clinical practice more rapidly and effectively requires additional investigation.

Table 1 Written Test Scores Before and After Training

Group	Pre-training Written Score	Post-training Written Score
Experimental Group 1	41.4%±10.6%	53.8%±12.6%
Experimental Group 2	40.4%±10.9%	52.6%±13.6%
Control Group	39.8%±10.5%	43.3%±10.8%

*P>0.05: No significant difference among three groups

**P<0.0167: No difference between Experimental Groups 1 and 2, but both significantly different from control group

#Written test scores converted to percentage

Table 2 Post-training Image Quality and Anatomical Structure Identification

Group	Image Quality Score	Structure Identification Score
Experimental Group 1	17.1±4.5	18.2±6.3
Experimental Group 2	16.0±4.1	17.0±6.1
Control Group	7.7±3.1	11.9±6.9

*P<0.0167: No difference between Experimental Groups 1 and 2, but both significantly different from control group

Table 3 Post-training Satisfaction Survey Results

Survey Item	Experimental Group 1 (n=21)	Experimental Group 2 (n=21)	Control Group (n=21)	P-value
Overall Satisfaction	Satisfied	Neutral	Dissatisfied	Satisfied
Cardiac Structure Identification				
Learning TTE				
Probe Manipulation				
Learning Likelihood to Recommend				
Ease of Use				

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