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Education

Structured Cardiac Assessment Outperforms Visual Estimation in Novice Ultrasound Users: A Randomized Controlled Trial

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□ **Abstract—Background: Two evidence-based techniques to determine left ventricular (LV) systolic function are taught in emergency medicine curricula. The first is a "structured approach," which qualitatively evaluates LV fractional shortening, E-point septal separation, and LV diameter. The other is the "eyeball method," which qualitatively estimates the LV ejection fraction (LVEF). Objective: The aim of this study was to determine whether the structured approach or the eyeball method was superior for teaching LVEF estimation to novices. Methods: Medical students were recruited to participate in our randomized controlled trial. Participants were randomized to the structured approach group or eyeball method group and completed one of two 15-min educational modules. Participants subsequently interpreted 12 echocardiogram clips to determine LV function. The primary outcome was the percentage of correct interpretations as determined by a cardiologist. Results: Seventy-four participants were invited to participate and 32 completed the study (15 in the structured approach and 17 in the eyeball method groups). The majority (30 of 32 [93.75%]) were first- and second-year medical students with no prior ultrasound training. The mean time to complete the training was similar between groups (16.8 vs. 17.8 min; $p = 0.66$). The primary outcome of percent of correct interpretations was significantly higher in the structured approach group compared with the eyeball method group (88.9% vs. 73.0%; $p < 0.01$). Conclusions: Training novice ultrasound users in a structured qualitative LV assessment method was more effective than the eyeball method. Learners were able to achieve high accuracy after a brief training intervention. These results may help inform best practices for undergraduate ultrasound curriculum development. © 2023 Published by Elsevier Inc.**

□ **Keywords—ultrasound; medical education; left ventricular ejection fraction**

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Introduction

Point-of-care ultrasound (POCUS) is internationally recognized as part of the scope of practice of emergency physicians (1–3). As such, virtually all Canadian and U.S. emergency medicine residency programs have developed ultrasound curricula with established core competencies (2,4). Some core competencies include, but are not limited to, focused assessment with sonography for trauma, identification of abdominal aortic aneurysms, identification of an intrauterine pregnancy, as well as identification

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of pericardial effusions and assessment of global cardiac contractility.

Two well-established point-of-care techniques to determine left ventricular (LV) systolic function have been described in the literature. The first is known as the "structured approach," which relies on visual estimation of LV fractional shortening, E-point septal separation (EPSS), and LV diameter (5,6). The other is an "eyeball method," where the operator qualitatively estimates the ejection fraction (EF) of the LV (7,8). When used by experienced emergency physicians, both methods have been found to correlate with more comprehensive quantitative methods that measure LVEF.

There is a paucity of evidence on which method is more effective for teaching novice ultrasound users how to estimate LV systolic function. To our knowledge, this is the first randomized study comparing the structured approach with the eyeball method for teaching visual estimation of LVEF using POCUS clips obtained in the emergency department.

Methods

We performed a randomized controlled trial of medical students with no prior ultrasound training at a single academic health sciences center in Toronto, Canada. Medical students were invited to participate in the study. Participants were randomized using a random number generator (Excel, version 16.61.1; Microsoft Corp) to either the eyeball method group or the structured approach group.

Participants in each group were provided a link to a separate web-based tutorial, with one group completing the structured approach training and the other completing the eyeball method training. The tutorials included instruction on basic ultrasound physics, the corresponding LV assessment method, 3 patient cases, and numerous LV assessment examples. Both tutorials were identical in length and used identical ultrasound images and clips. They only varied in the way LVEF estimation was taught. In the structured approach group, participants were taught to use visual estimations of LV fractional shortening, EPSS, and LV internal diameter. Although students did not take caliper measurements for each of these three LV assessment tools, they were taught how to visually estimate these measurements using the depth markers located on the ultrasound screen. A normal LV fractional shortening was taught as a decrease by more than one-third of the LV maximal diastolic diameter. A normal EPSS was taught to be < 1 cm and a normal LV internal diameter was taught to be < 5 cm at end diastole. In the eyeball method group, participants were taught to assess LV function using global evaluation of the contractility of the LV. Both tutorials were developed by two expert emergency physicians with fellowships in POCUS.

Each participant was subsequently asked to interpret two practice parasternal long-axis ultrasound clips and determine whether the LVEF was normal or abnormal. Normal LVEF was defined as EF $> 55\%$ and abnormal LVEF was defined as EF $< 55\%$. One of these clips demonstrated a normal LVEF and the other an abnormal LVEF. Participants continued to the quiz regardless of whether they answered the practice questions correctly or incorrectly. This was followed by a quiz that consisted of interpreting 12 different cardiac ultrasound clips. All clips were obtained by POCUS fellowship–trained emergency physicians in the emergency department. The clips were randomly selected from a digital archive of POCUS scans performed in the emergency department. The clips were selected to represent a broad range of image quality and LV function. Examples of both normal and abnormal POCUS scans can be found in the Supplementary Material. A questionnaire was completed by each participant before and after completing the study to determine their experience and confidence levels with the material (Supplementary Material). The time spent completing the tutorial and quiz was captured by the web-based tutorial.

The primary outcome was the percentage of correct interpretations as determined by a level 3 American Society of Echocardiography board–certified cardiologist blinded to the participant groups. Secondary outcomes included differences in time to completion of the quiz and confidence scores between the two groups.

Ordinal data were analyzed separate from continuous data. Ordinal data were represented as percentages within each group. Continuous data were represented as mean (SD). Pearson χ^2 test was used to identify any difference in post-test confidence scores. Student's t-test was used to identify any difference in the percentage of correct interpretations, as well as quiz time to completion between the structured assessment group and eyeball method groups. Significance level was set at $\alpha = 0.05$. A sample size of 32 participants was required to demonstrate a 10% difference between groups and the sample size was determined *a priori.*

Results

A total of 74 participants expressed interest in the study and 32 of 74 (43.2% response rate) completed the study (15 in the structured approach and 17 in the eyeball method groups) (Figure 1). The remaining 42 participants did not complete the study. The majority (30 of 32 [93.8%]) were first- and second-year medical students and none had prior ultrasound training. All 32 participants disclosed that they have never assessed a patients LVEF and

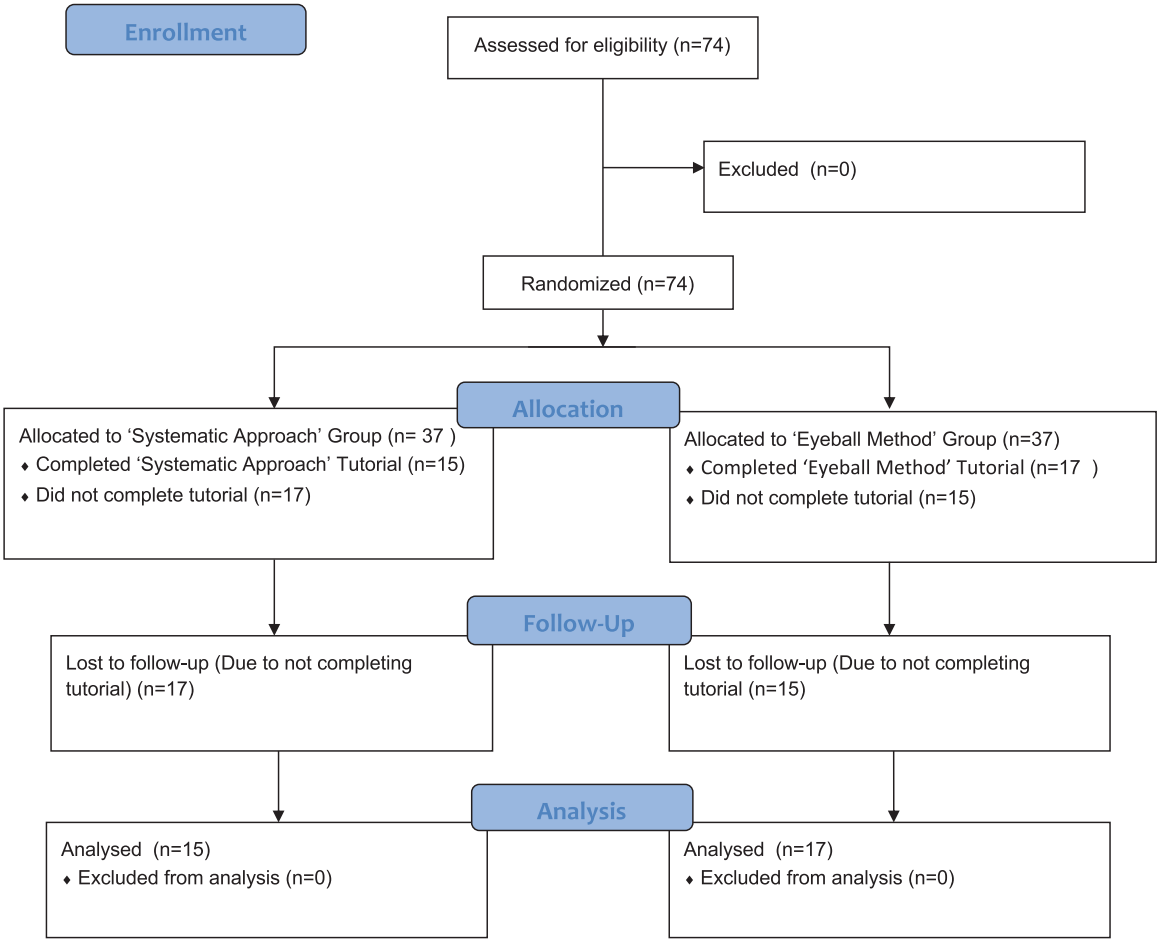

Figure 1. Participant flow diagram.

Table 1. Baseline Demographic Characteristics of Participants

Characteristic	Structured Assessment (n = 15)	Eyeball Method (n = 17)
Year of training, n (%)		
First-year medical student	8 (53.3)	9 (52.9)
Second-year medical student	6 (40)	7 (41.2)
Third-year medical student	1 (6.7)	1 (5.9)
Prior experience with POCUS, n (%)	0 (0)	0 (0)
Experience assessing LVEF with POCUS, n (%)	0 (0)	0 (0)
Confident assessing LVEF, n (%)	0 (0)	0 (0)

LVEF = left ventricular ejection fraction; POCUS = point-of-care ultrasound.

were "not at all confident" at interpreting LVEF on ultrasound. There were no differences in any of the baseline characteristics between the two groups (Table 1).

The primary outcome of LVEF assessment scores was significantly higher in the structured approach group compared with the eyeball method group (88.9% vs. 73.0%; $p < 0.01$) (Table 2). The effect size of was determined by Cohen's d, which was calculated at 1.14. The mean time to complete the training was similar between the groups (16.8 vs. 17.8 min; $p = 0.66$).

Confidence levels in both groups significantly increased after training, with an increase of 73.3% in the structured group ($p < 0.01$) and an increase of 64% in the eyeball group ($p < 0.01$). However, there were no significant differences between the groups in the final post-tutorial confidence levels (73.3% vs. 64.7%; $p = 0.65$)

Table 2. Primary and Secondary Outcome Results

Result	Structured Assessment	Eyeball Method	*p* Value
Correct interpretation, %, mean (SD)	88.9 (12.9)	73.0 (14.9)	0.0032
Time to quiz completion, min, mean (SD)	16.8 (0.5)	17.2 (0.7)	0.878
Confident in assessing LVEF post-tutorial, n (%)	11 (73.3)	11 (64.7)	0.65

LVEF = left ventricular ejection fraction.

(Table 2). There was no significant difference between the two groups in the time to complete the quiz (17.2 vs. 16.8 min; $p = 0.88$).

Discussion

In this study, training novice ultrasound users in a structured qualitative LV assessment method was more effective than the commonly used eyeball method for interpreting cardiac POCUS clips. Learners in both groups were able to achieve moderately high accuracy after a brief training intervention.

The eyeball method is recognized among experienced clinicians to provide reasonably accurate LVEF estimations (4–6). In 2002, Moore et al. were the first to report that emergency physicians were able to accurately estimate LVEF using visual estimation in hypotensive patients (8). This finding was supported by two additional studies, one by Randazzo et al. in 2003 and the other by Shahgaldi et al. in 2009 (7,8). These studies suggest that not only are visual estimates almost as accurate as formal quantitative methods at determining LVEF, but also that visual estimates done by emergency physicians are as accurate as those done by board-certified cardiologists.

As the use of POCUS became more widely adopted within emergency departments, additional bedside qualitative estimates were put into practice by emergency physicians to potentially increase their accuracy at estimating LVEF. In 2013 McKaigney et al. reported that EPSS measurements obtained by emergency physicians had a higher level of agreement with measured LVEF than visual estimates (5). In addition, in 2004, Pershad et al. reported that emergency physicians determined LVEF accurately using fractional shortening compared with a board-certified cardiologist (9). Although these studies suggest both EPSS and fractional shortening are very accurate, it is unclear whether they are superior to global estimation of LV function alone. In 2021, Bahl et al. compared the accuracy of fractional shortening, EPSS, and visual estimation at evaluating LVEF compared with cardiologist performed echocardiograms (10). They found that among experienced clinicians, visual estimation was the most accurate of the three.

Although visual estimates of LVEF have been found to be accurate among experienced clinicians, we found that novice ultrasound users performed better when taught to use a structured approach to estimate LVEF. This is likely because teaching a structured approach to LVEF assessment builds a framework around which learners can more objectively analyze echocardiograms. We suspect that this is why our learners who received teaching around a structured approach performed significantly better than those students who were taught the eyeball method.

We found no difference between the two groups in the speed at which participants were able to complete the post-tutorial quiz and their post-quiz confidence scores (Table 2). Not surprisingly, confidence levels in both groups increased after training. Despite a performance advantage in one group, the final confidence levels were similar. This may be explained by the fact that we did not provide immediate feedback to any of our participants during the quiz.

Limitations

This study has several important limitations. First, this study assessed image interpretation only, and not image acquisition. Although cardiac POCUS image acquisition is a critical skill, it has already been found to be easily obtained by learners (11). Therefore, our study focused primarily on image interpretation. Future studies should evaluate whether these results are consistent for ultrasound scans performed in real time. In addition, it is unclear whether the skills learned would last beyond the immediate period after the training module. It would be important to assess long-term retention in future studies. This study had a relatively small sample size; however, it was powered *a priori* to detect a difference of 10% between the groups. Although we were able to meet the power of the study, future studies should validate these findings in a larger sample size. Finally, only 12 POCUS clips were used for the assessment phase of this study, which may not reflect the entire spectrum of disease in an emergency population. However, we used real-world POCUS scans obtained in the emergency department and included a wide range of image quality and LV function.

Conclusions

This study demonstrated that a structured approach was more effective than the eyeball method for teaching LV function assessment in novice ultrasound users. These results may help inform best practices for undergraduate ultrasound curriculum development. This approach does not require any quantitative measurements and did not take longer to teach or apply than the commonly used eyeball method. POCUS curricula should consider incorporating the structured approach into their training for inexperienced learners. Additional larger studies that include real-time image generation are needed to validate these findings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jemermed.2023.05.018.

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