Focused Transthoracic Echocardiography During Critical Care Medicine Training: Curriculum Implementation and Evaluation of Proficiency*

Anne-Sophie Beraud, MD[1]; Norman W. Rizk, MD[2]; Ronald G. Pearl, MD, PhD[3]; David H. Liang, MD, PhD[1]; Andrew J. Patterson, MD, PhD[3]

Objectives: We designed and implemented a focused transthoracic echocardiography curriculum for critical care medicine fellows participating in 1- and 2-year training programs. We quantitatively evaluated their proficiency in focused transthoracic echocardiography.

Design: Prospective study evaluating curriculum implementation and objective assessment of focused transthoracic echocardiography proficiency.

Setting: Medical and surgical ICUs at an academic teaching hospital. Simulation laboratory.

Subjects: Eighteen critical care medicine fellows.

Interventions: Training in focused transthoracic echocardiography followed by proficiency testing.

Measurements and Main Results: We assessed the ability of critical care medicine fellows to obtain and interpret focused transthoracic echocardiography images from critically ill patients and a from transthoracic echocardiography simulator. Using a cognitive examination test, we also evaluated each fellow's knowledge with regard to focused transthoracic echocardiography and each fellow's ability to interpret prerecorded focused transthoracic echocardiography images. After training, critical care medicine fellows were able to rapidly obtain five essential focused transthoracic echocardiography views: parasternal long axis, parasternal short axis, apical four chamber, subcostal four chamber, and subcostal inferior vena cava. Fellows were also able to expeditiously identify four important abnormalities: asystole, left ventricular dysfunction, right ventricular dilation and dysfunction, and a large pericardial effusion.

Conclusions: A focused transthoracic echocardiography curriculum that includes quantitative measures of proficiency can be integrated into critical care medicine fellowship training programs.

(*Crit Care Med* 2013; 41:e179–e181)

Key Words: critical care medicine fellow; curriculum; focused transthoracic echocardiography; proficiency

***See also p. 2063.**

[1]Division of Cardiovascular Medicine, Department of Medicine, Stanford University Medical Center, Stanford, CA.

[2]Division of Pulmonary Critical Care, Department of Medicine, Stanford University Medical Center, Stanford, CA.

[3]Division of Critical Care Medicine, Department of Anesthesia, Stanford University Medical Center, Stanford, CA.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccmjournal).

Dr. Patterson lectured and served as an instructor for SCCM's Fundamentals of Critical Care Ultrasound Courses. The remaining authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: asberaud@stanford.edu

DOI: 10.1097/CCM.0b013e31828e9240

The usefulness (1), scope (2), and training requirements (3) for focused transthoracic echocardiography (F-TTE) have been outlined in consensus statements. However, few descriptions of teaching curricula and methods for assessment of proficiency have been published (4–6). In this report, we describe implementation of an F-TTE curriculum for critical care medicine (CCM) fellows and the methods used to evaluate proficiency. The F-TTE curriculum consisted of didactic lectures and bedside scanning instruction by a cardiologist at the beginning of each CCM fellow's clinical training. At the end of the first year of CCM training, each trainee's proficiency in F-TTE was measured using 1) an assessment of the quality of images obtained and the accuracy of interpretations made during examinations of three critically ill patients; 2) an evaluation of the capacity to obtain and interpret F-TTE images using an ultrasound simulator; 3) a computer-based cognitive evaluation of F-TTE knowledge and image evaluation.

MATERIALS AND METHODS

The subjects were trainees in the CCM fellowship program at Stanford University. All subjects were physicians with prior residency training in anesthesiology ($n = 6$), internal/emergency medicine ($n = 5$), or internal medicine ($n = 7$). The instructor was a cardiologist board-certified in echocardiography (7). The F-TTE curriculum was based on a consensus statement by the American Society of Echocardiography (2). The goals of F-TTE as defined in the curriculum were to answer four clinical questions: Is the left ventricular (LV) function normal? Is the right ventricular (RV) function normal? Is there a pericardial effusion? What is the volume status of the patient? The training consisted of weekly lectures (total 8 hr) and 15 hours of bedside ultrasound scanning instruction. The lectures were based on images and case studies, with digital recordings available in the **supplemental data** (Supplemental Digital Content 1, http://links.lww.com/CCM/A670). Bedside scanning instruction was performed by the cardiologist during one-on-one sessions in the ICU. A Sonosite M-Turbo (Sonosite, Bothell, WA) with phased-array cardiac transducer was used for image acquisition. Images were transferred and stored in the Stanford University Hospital PACS system.

After completion of the curriculum, trainees were encouraged to perform, record, and complete reports for as many F-TTE examinations as possible. All examinations and reports were reviewed by the cardiologist instructor. During evaluation sessions and by e-mail, feedback was provided to each fellow regarding the quality of the images obtained and interpretation.

At the end of the first year of CCM training, F-TTE proficiency was assessed. To evaluate each fellow's ability to obtain adequate acoustic windows and views in the clinical realm, the last three consecutive F-TTE examinations recorded during routine evaluations of critically ill patients were reviewed. Examinations were considered satisfactory if all the following objectives were achieved: the LV and RV were visualized in at least two different views with adequate semiquantitative estimation of their function, the pericardial space was adequately assessed for the presence or absence of effusion, and the inferior vena cava (IVC) was identified with its diameter correctly measured.

A simulator test was then administered using a CAE Vimedix ultrasound simulator. Each fellow's performance was evaluated during five scenarios: severe LV dysfunction, RV dilation and dysfunction, circumferential pericardial effusion, asystole, and a normal heart. Each fellow was instructed to identify abnormalities (if any) as quickly as possible while obtaining the following views for each scenario: parasternal long axis, parasternal short axis at the level of the papillary muscles, apical four chamber, subcostal four chamber, and subcostal view of the IVC. When a fellow considered a view adequate for interpretation, she/he signaled the instructor who confirmed and recorded the time or rejected the view without providing further comment. If the view was rejected, the fellow continued scanning. The accuracy of diagnosis, the time needed to make the diagnosis, and the time required to obtain each view were recorded. A maximum of 300 seconds was allowed to obtain each view. To validate the simulator test, nine novices (medical students without prior exposure to echocardiography) and five experts (experienced cardiologist and sonographers) were also evaluated. The average diagnosis time and average total scanning time (averaged across five scenarios for each participant) were compared among the three groups using one-way analyses of variance (ANOVA) with Bonferroni correction to adjust for multiple pairwise comparisons.

Next, each fellow participated in a cognitive examination. This test was administered using CourseWork, Stanford University's learning management system. The examination included questions regarding image acquisition and interpretation of five prerecorded studies. The maximum possible score was 40. Ten of 18 trainees completed a baseline cognitive test prior to the ultrasound training. A comparison of the cognitive pretest and post-test results was performed using two-tailed paired *t* test.

RESULTS

Eighteen CCM fellows completed the curriculum and proficiency evaluation, of which 13 (72%) did not have any prior experience with TTE. The average bedside instruction time for each fellow was 15 hours (ranged from 10 to 41 hr), during which 25 ± 7 proctored examinations were performed. The proficiency evaluation occurred on average after 12.7 months (8–22) of training. Each trainee performed an average of 21 ± 20 (2–71) independent examinations. The last three of these independent examinations were reviewed by the instructor and evaluated for adequacy of image acquisition and validity of the interpretations. The diagnoses were correct in all of these reviewed independent examinations.

During the simulator sessions, fellows diagnosed the following abnormalities (average diagnosis time ± SD): asystole (17 ± 14 s), LV dysfunction (45 ± 55 s), RV dilation and dysfunction (109 ± 82 s), pericardial effusion (21 ± 21 s), and a normal heart in a patient with poor transthoracic windows (193 ± 110 s). RV dysfunction was the only diagnosis missed, by one fellow and three novices. The fellows' average diagnosis time (72 ± 38 s, mean ± SD) was significantly different from that of the novices (185 ± 86 s, $p < 0.001$) and from that of the experts (18 ± 7 s, $p < 0.001$; **Fig. 1**, one-way ANOVA, $p < 0.001$). During the simulator evaluation, fellows obtained

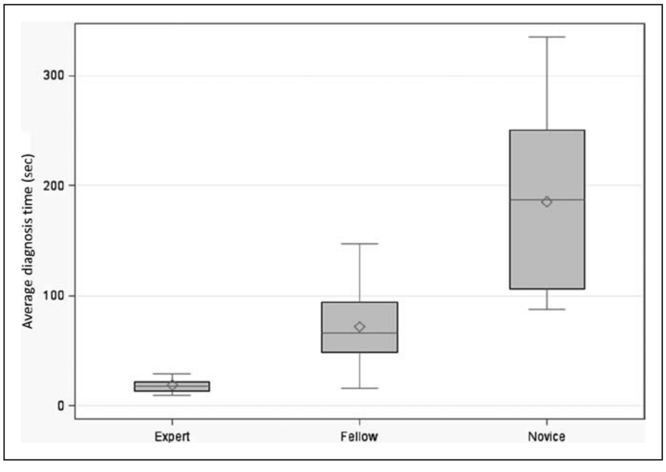

Figure 1. Comparison of diagnosis time (mean ± SD) for the five clinical scenarios between the novices ($n = 9$), fellows ($n = 18$), and experts ($n = 5$).

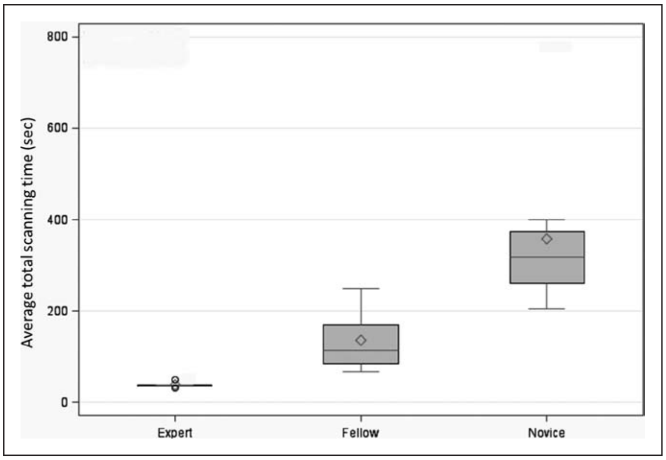

Figure 2. Comparison of average scenario scanning time (mean ± SD) between the novices ($n = 9$), fellows ($n = 18$), and experts ($n = 5$).

the following F-TTE views: parasternal long axis (24 ± 21 s), parasternal short axis (18 ± 13 s), apical four chamber (25 ± 25 s), subcostal four chamber (20 ± 16 s), and IVC (13 ± 13 s). The fellows' average total scanning time per scenario (136 ± 63 s, mean ± SD) was significantly different from novices (358 ± 170 s, $p < 0.001$) and from experts (38 ± 6 s, $p < 0.001$; **Fig. 2**, one-way ANOVA, $p < 0.001$). The mean and median scores for the cognitive baseline examination were 84% and 83% (range, 71–97%). For the 10 fellows who completed pre- and postexaminations, the mean score improved from 84% to 91% ($p = 0.02$).

DISCUSSION

Previously described approaches for teaching and evaluating proficiency in TTE involved comparisons of trainees' reports to those generated by experts (4, 6) or evaluations by experts of images acquired by trainees (5, 8, 9). These curricula consisted of 6–12 hours of training. Our F-TTE teaching program is longer. The amount of training per fellow ranges from 10 to 41 hours (average 15 hr). Our assessment of proficiency is multimodal and involves assessments of each trainee's ability to obtain and interpret images, as well as knowledge.

Our approach has limitations. For instance, our curriculum includes an assessment of proficiency at the end of the academic year. This approach facilitates evaluation of enduring echocardiography knowledge and skills. However, it allows learning not associated with the training program per se to confound interpretation of the curriculum's effectiveness. The study design did not allow us to detect a correlation between duration of training and acquisition of proficiency. Another limitation of our study is that a single instructor recorded all scanning and interpretation times.

Our approach does have several strengths. First, we were able to incorporate the metric of time into our evaluations of scanning and image interpretation. In doing so, we were able to include a surrogate for performing TTE examinations in time-pressured situations in which results influence immediate patient management (10). We were also able to include evaluations of mechanically ventilated critically ill patients (as well as simulator images) into the testing regimen, which we believe increased the degree of difficulty of the testing.

CONCLUSIONS

An F-TTE curriculum that includes assessment of image acquisition and interpretation skills, as well as a cognitive examination, can be effectively integrated into CCM fellowship programs. A proficiency evaluation system such as the one described in this report may be considered an appropriate tool for determining when fellows have been adequately prepared for use of F-TTE in independent practice.

REFERENCES

1. Jensen MB, Sloth E, Larsen KM, et al: Transthoracic echocardiography for cardiopulmonary monitoring in intensive care. *Eur J Anaesthesiol* 2004; 21:700–707
2. Labovitz AJ, Noble VE, Bierig M, et al: Focused cardiac ultrasound in the emergent setting: A consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr* 2010; 23:1225–1230
3. International expert statement on training standards for critical care ultrasonography. *Intensive Care Med* 2011; 37:1077–1083
4. Vignon P, Mücke F, Bellec F, et al: Basic critical care echocardiography: Validation of a curriculum dedicated to noncardiologist residents. *Crit Care Med* 2011; 39:636–642
5. Jones AE, Tayal VS, Kline JA: Focused training of emergency medicine residents in goal-directed echocardiography: A prospective study. *Acad Emerg Med* 2003; 10:1054–1058
6. Vignon P, Dugard A, Abraham J, et al: Focused training for goal-oriented hand-held echocardiography performed by noncardiologist residents in the intensive care unit. *Intensive Care Med* 2007; 33:1795–1799
7. Quiñones MA, Douglas PS, Foster E, et al; American College of Cardiology; American Heart Association; American College of Physicians-American Society of Internal Medicine; American Society of Echocardiography; Society of Cardiovascular Anesthesiologists; Society of Pediatric Echocardiography: ACC/AHA clinical competence statement on echocardiography: A report of the American College of Cardiology/American Heart Association/American College of Physicians-American Society of Internal Medicine Task Force on Clinical Competence. *J Am Coll Cardiol* 2003; 41:687–708
8. Manasia AR, Nagaraj HM, Kodali RB, et al: Feasibility and potential clinical utility of goal-directed transthoracic echocardiography performed by noncardiologist intensivists using a small hand-carried device (SonoHeart) in critically ill patients. *J Cardiothorac Vasc Anesth* 2005; 19:155–159
9. Royse CF, Haji DL, Faris JG, et al: Evaluation of the interpretative skills of participants of a limited transthoracic echocardiography training course (H.A.R.T.scan course). *Anaesth Intensive Care* 2012; 40:498–504
10. Oren-Grinberg A, Gulati G, Fuchs L, et al: Hand-held echocardiography in the management of cardiac arrest. *Anesth Analg* 2012; 115:1038–1041