The Echocardiography “Boot Camp”: A Novel Approach in Pediatric Cardiovascular Imaging Education

Shiraz A. Maskatia, MD, Carolyn A. Altman, MD, Shaine A. Morris, MD, MPH, and Antonio G. Cabrera, MD, Houston, Texas

Background: Dynamic training schedules introduce novel challenges to medical specialty training programs that require manual dexterity. The aim of this study was to examine the effect of a 3-day, intensive pediatric echocardiography course (“boot camp”) on trainee self-efficacy and on the acquisition and short-term retention of basic echocardiographic knowledge and skills for first-year pediatric cardiology fellows (CFs).

Methods: The boot camp consisted of hands-on structured practice guided by sonographers and cardiology faculty members, didactic lectures, and reading. Pre–boot camp experience was assessed using an experience score. Outcome measures included written precamp and postcamp examinations, a performance-based test, precamp and postcamp self-efficacy assessments, and the number and quality of echocardiographic examinations performed in the first 3 months of fellowship.

Results: Six CFs completed the boot camp. Two of the six CFs reported experience scores of 2 out of 10, whereas the remainder reported experience scores of 0 out of 10. Performance-based test scores ranged from 68 to 99 out of 147. All six CFs reported precamp self-efficacy scores of 21 (the minimum score), compared with median postcamp scores of 82 (range, 49–94) (P = .01). Scores on the written examination improved from median of 16 (range, 11–18) to 23.5 (range, 22–28) (P = .01). CFs who completed the boot camp completed 28 independent echocardiographic examinations (median, 4 per CF) during the first 3 months of fellowship, an increase from six independent examinations (median, 1 per CF) by CFs during the year before institution of the boot camp (P = .030). Echocardiograms obtained by CFs who had completed the boot camp scored higher on total quality (P = .004), overall two-dimensional image quality (P = .011), functional assessments (P = .015), and assessment for pericardial effusion (P = .031).

Conclusions: The echocardiography boot camp improves self-efficacy in performing an echocardiographic examination and the acquisition and short-term retention of skills and knowledge required to perform pediatric echocardiography. (J Am Soc Echocardiogr 2013;26:1187-92.)

Keywords: Pediatric cardiology, Education, Fellowship training

Pediatric cardiology as a field began in the 1940s. Despite a >60-year history of pediatric cardiology training, sparse literature exists on training fellows in pediatric cardiology. According to published training guidelines, all pediatric cardiologists must be proficient in echocardiography upon completion of their training. Furthermore, transthoracic echocardiography is the mainstay for diagnosing congenital and acquired heart disease in children. Accurate echocardiography is crucial to providing appropriate patient management. Diagnostic errors are rare in pediatric echocardiography. However, when they occur, they often lead to preventable errors. These errors occur more frequently when echocardiograms are performed at night, when they are performed by those with less experience in congenital heart disease, and when patients have higher complexity or uncommon heart diseases.

Dynamic training schedules and duty-hour restrictions introduce novel challenges in training medical professionals, particularly in procedural specialties that require manual dexterity. Although transthoracic echocardiography is not an invasive procedure, learning to perform echocardiography accurately requires manual dexterity and repeated exposure. Traditionally, cardiology fellows (CFs) obtain much of this repeated exposure during on-call echocardiographic examinations, performed at night or on weekends. During these on-call periods, fellows typically have the option of attempting to perform echocardiography independently with staff cardiologist oversight, but not at the bedside. Of course, if there is a clinical need for an expeditious examination, the staff cardiologist or sonographer performs the study. During the first 3 months of fellowship, these opportunities to perform echocardiography independently

From The Lillie Frank Abercrombie Section of Pediatric Cardiology, Baylor College of Medicine, Texas Children’s Hospital, Houston, Texas.

Funding was obtained through the Department of Pediatrics at Baylor College of Medicine Educational Project Scholarship Award. This work was also supported by the Section of Pediatric Cardiology Cardiovascular Clinical Research Core at Texas Children’s Hospital/Baylor College of Medicine.

Reprint requests: Shiraz A. Maskatia, MD, Texas Children’s Hospital, 6621 Fannin Street, MC 19345-C, Houston, TX 77030 (E-mail: samaskat@bcm.edu).

0894-7317/$36.00

Copyright 2013 by the American Society of Echocardiography.

http://dx.doi.org/10.1016/j.echo.2013.06.001

1187
Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>Cardiology fellow</td>
</tr>
<tr>
<td>EXP</td>
<td>Experience score</td>
</tr>
<tr>
<td>PBT</td>
<td>Performance-based test</td>
</tr>
<tr>
<td>2D</td>
<td>Two-dimensional</td>
</tr>
</tbody>
</table>

Cardiologists to obtain and interpret on-call echocardiograms. This change in practice has resulted in further reduction in the on-call echocardiographic experience for CFs.

The term “boot camp” has been used in a variety of settings, with marked variability in the objectives and structure of various forms of boot camps in the published literature. Typically, the term refers to short, intensive courses during the initial periods of training designed to advance the initial acquisition of practical technical skills. These courses generally involve a large component of structured practice, with feedback from educators. Short courses in echocardiography have demonstrated benefit to medical personnel who treat adults with acquired heart disease. We hypothesize that an intensive, 3-day pediatric echocardiography curriculum (boot camp) is an effective educational intervention to improve self-efficacy in performing echocardiography as well as the acquisition and short-term retention of basic echocardiographic concepts and skills for first-year pediatric CFs. The goal of the boot camp is to provide CFs with a boost up the learning curve, such that they are more prepared to take advantage of educational opportunities provided during cardiology fellowship.

**METHODS**

**Curriculum**

We based the curriculum design on David Kolb’s model of experiential learning. Kolb is an educational theorist well known for popularizing the notion that learning frequently occurs through reflection on previous experiences. He defined learning as the interaction of content and experience, whereby each transforms the other. He described four learning styles: accommodating (processing a concrete experience through active experimentation), converging (experimenting with an abstract concept), and assimilating (reflecting on an abstract concept). Often, medical learners take advantage of various learning styles. Therefore, we designed the course to involve assessment and reflection of prior cardiologic and echocardiographic knowledge obtained using a precamp written examination and survey, precamp reading focused on normal cardiac anatomy and basics of echocardiography, didactic lectures performed by faculty members in the section of pediatric cardiology, and hands-on echocardiography moderated by experienced pediatric sonographers and performed on patient volunteers.

There were a total of 19 sessions throughout the camp, all of which were attended by all six CFs. Of these, six were lecture-based sessions, and 13 were hands-on echocardiography sessions. Cardiology staff members or senior fellows gave all lectures. The multimedia echocardiographic planes lecture was a 2-hour session, during which echocardiographic planes were described with the aid of diagrams and a handheld heart model. After each description of an echocardiographic plane, the view was demonstrated on a live model. Cardiac ultrasonographers from the Texas Children’s Hospital echocardiography lab proctored all hands-on echocardiography sessions. Hands-on sessions were held in the echocardiography rooms in our cardiovascular clinic research core. Other than the multimedia echocardiographic planes lecture, all sessions were 1 hour in length. The details of the structure of the boot camp are provided in Figure 1.

**Subject, Instructor, and Patient Recruitment**

All subjects in the study were incoming first-year CFs. Informed consent was obtained before the study. All six incoming CFs chose to participate. A total of 52 pediatric patient volunteers were recruited for the hands-on echocardiography portion of the boot camp. Volunteers received financial compensation. Patients with no structural heart disease or simple, repaired defects were included in the study. Patients with poor acoustic windows or who were deemed as likely to be uncooperative were excluded. Instructors for the course were pediatric ultrasonographers with Internsocietal Accreditation Commission accreditation in pediatric echocardiography and experience in training CFs. The study was approved by the Baylor College of Medicine Institutional Review Board.

**Precamp and Postcamp Assessments**

Before the initiation of the boot camp or the precamp reading, all CFs performed a precamp survey to assess prior experience in echocardiography, a precamp written examination, and a precamp assessment of self-efficacy in performing basic pediatric echocardiography. Upon completion of the boot camp, all CFs repeated the written examination and assessment of self-efficacy. Additionally, a proctored performance-based test (PBT) was administered.

The written examination contained 18 questions, arranged in a multiple-choice format. Five questions involved multiple correct or incorrect answers, in the format of “choose all that apply.” These questions were weighted more heavily, to arrive at a maximum possible score of 30 points. Question topics included practical applications of basic ultrasound physics, interpretation of echocardiographic findings (e.g., interventricular septal flattening), interpretation of spectral Doppler velocities and gradients, calculation and application of shortening fraction and ejection fraction, and the identification of normal structures in standard echocardiographic views.

The precamp survey collected CFs’ prior experience in four key areas, on a 10-point scale: reading an echocardiogram, performing echocardiography, cardiac anatomy, and the physics of echocardiography. These four parameters were summed to obtain an experience score (EXP), on a 40-point scale. On the basis of the results of the precamp survey, CFs were divided into two groups: those with prior experience performing echocardiography (EXP = 0) and those with prior experience performing echocardiography (EXP ≥ 1).

The CFs reported precamp and postcamp self-efficacy in performing echocardiography. Self-efficacy is defined as a measure of one’s own ability to complete tasks or achieve a stated goal. Self-efficacy was assessed using seven-point (1 = minimum, 4 = satisfactory, 7 = maximum) measures of 21 echocardiographic objectives, resulting in a 147-point scale (Table 1). A seven-point scale was chosen to optimize the power of the analysis. Objectives included the attainment of standard echocardiographic views, assessment for valvar pathology, assessment of systolic function by various methods, assessment for aortic arch obstruction, and assessment for pericardial effusion. Objectives also included factors involved in image
Day 1 | Day 2 | Day 3
--- | --- | ---
Welcome | Fundamentals of Doppler | Self-Guided Review
Basic Anatomy | Systolic Function | Suprasternal
Echo Physics / “Knob-belay” | Using Spectral Doppler | Aortic Arch
Multimedia Echo Planes | Apical 4 Chamber | Pulmonary Veins
Holding and Maneuvering the Probe | Apical 2 and 5 Chamber | Subcostal
Parasternal Long Axis | Obtaining an Ejection Fraction | Self-Guided Review
Parasternal Short Axis | | |

Figure 1 The pediatric echocardiography boot camp curriculum. *White boxes* represent didactic and interactive lectures. *Shaded boxes* represent hands-on echocardiography.

<table>
<thead>
<tr>
<th>Objective</th>
<th>≤3</th>
<th>≤4</th>
<th>≤5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasternal long-axis view</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Parasternal short-axis view</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>M-mode acquisition at the papillary muscles</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Color Doppler acquisition of the pulmonary valve</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Apical four-chamber view</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Apical five-chamber view</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Color Doppler acquisition of the aortic valve</td>
<td>0</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Apical two-chamber view</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>EF (Simpson’s method)</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>EF (bullet method)</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Aortic arch by 2D imaging</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Assess for aortic arch obstruction</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Measure aortic isthmus</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Pulmonary veins (2D)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pulmonary veins (color Doppler)</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Assess for pericardial effusion</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Use of proper frequency probe</td>
<td>0</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Use of zoom/depth</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Use of gain/time-gain compensation</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Use of focal zone</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Use of pulsed-wave vs continuous-wave Doppler</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

EF, Ejection fraction; 2D, two-dimensional.
Numbers of CFs who achieved scores of ≤3, ≥4, and ≥5 are provided. All assessments were on a seven-point scale.

optimization, including choice of the appropriate frequency probe, the use of zoom and depth, the use of overall gain and time-gain compensation, appropriate placement of the focal zone, and the use of pulsed-wave versus continuous-wave Doppler. The selection of echocardiographic objectives was based on basic guidelines and standards for the performance of pediatric echocardiography by the American Society of Echocardiography.21

All CFs also completed a postcamp PBT. Our expectation in designing the study was that no CF would have more than minimal experience in performing echocardiography before the boot camp. Therefore, a precamp PBT was not offered. During the PBT, the CFs demonstrated each of the 21 echocardiographic objectives, graded on a seven-point scale, for easy comparison with postcamp self-efficacy scores. PBTs were performed on preselected pediatric patients with normal anatomy and excellent acoustic windows. All PBTs were assessed by a single observer, with expertise in training fellows in echocardiography (C.A.A.).

To evaluate short-term retention of skills and self-efficacy, we assessed CFs’ performance during the first 3 months of fellowship. We measured the total number of echocardiographic examinations in which a CF participated in the acquisition and the number of examinations performed independently by a CF in the first 3 months of fellowship. Echocardiographic examinations counted as having been independently performed must have had a CF as the sole sonographer, have not been repeated the same night (for overnight studies) or the same day (for weekend studies), have been officially ordered by the team caring for the patient as part of routine clinical care, and have been officially interpreted by a staff cardiologist. Additionally, we assessed the quality of echocardiograms obtained independently. A blinded observer (C.A.A.) reviewed and scored deidentified echocardiograms obtained independently by CFs. Echocardiograms were scored using a 100-point scoring system modified from a scoring system used as part of our standard echocardiographic curriculum (Table 2). This echocardiographic quality score involves assessing whether the information supplied was sufficient given the indication for the echocardiographic examination, the quality of two-dimensional (2D) images and Doppler interrogation, accurate functional measures, and evaluation for pericardial effusion. The overall 2D image quality score was a global assessment of image quality. In addition to the overall 2D image quality score, we calculated an image optimization score, which takes into account the choice of transducer; the use of 2D gain and time-gain compensation; and sector width, depth, and focus. The Doppler score incorporates assessments of the use of pulsed-wave and continuous-wave Doppler, color scale and gain, and angle of interrogation. The function score takes into account accurate and appropriate measurement of ejection fraction (using the bullet or modified Simpson’s biplane method) and shortening fraction. For the above analyses, CFs from the year before the institution of the boot camp (n = 5) were used as historical controls. There was no change in the call system, availability of echocardiographic equipment on call, or expectations and objectives during the standard echocardiogram curriculum from the year before the year after institution of the boot camp.

Data Analysis

We compared precamp scores of self-efficacy assessments and the written examinations with postcamp scores using a Friedman analysis, used to analyze repeated measures of nonparametric data. Comparisons between EXPs (range, 0–40) and postcamp assessments were performed using Spearman’s correlation. Comparisons between numbers and quality scores of echocardiograms obtained between CFs who underwent boot camp and CFs from the year prior were performed using the Mann-Whitney test. A P value of .05 was used as criterion for statistical significance in all analyses. All statistical analyses were performed using SPSS version 20.0 (IBM, Chicago, IL).

RESULTS

Six CFs completed the boot camp. Precamp and postcamp assessment scores are depicted in Figure 2. All six CFs reported precamp self-efficacy scores of 21 (the minimum score), compared with the median postcamp self-efficacy score of 82 (range, 49–94)
Table 2 Results of blinded evaluation of quality of echocardiograms obtained by CFs before and after the institution of the boot camp

<table>
<thead>
<tr>
<th>Variable</th>
<th>No boot camp (n = 6)</th>
<th>Boot camp (n = 28)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score (maximum, 100)</td>
<td>42 (30–58)</td>
<td>57 (34–71)</td>
<td>.004</td>
</tr>
<tr>
<td>Sufficient information (maximum, 14)</td>
<td>8 (4–8)</td>
<td>10 (6–12)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Overall two-dimensional image quality (maximum, 14)</td>
<td>6 (2–9)</td>
<td>9 (4–12)</td>
<td>.011</td>
</tr>
<tr>
<td>Optimization score (maximum, 37)</td>
<td>21 (16–27)</td>
<td>24 (16–32)</td>
<td>.066</td>
</tr>
<tr>
<td>Doppler score (maximum, 19)</td>
<td>12 (9–13)</td>
<td>13 (3–15)</td>
<td>.809</td>
</tr>
<tr>
<td>Function score (maximum, 22)</td>
<td>2 (0–10)</td>
<td>8 (0–18)</td>
<td>.015</td>
</tr>
<tr>
<td>Pericardial effusion (maximum, 8)</td>
<td>1 (0–2)</td>
<td>3 (1–6)</td>
<td>.031</td>
</tr>
</tbody>
</table>

Data are expressed as median (range).

DISCUSSION

Our study is the first to demonstrate the feasibility and short-term effectiveness of a 3-day pediatric echocardiography boot camp for fellows in training. Echocardiography is a skill that requires not only knowledge of cardiac anatomy and physiology but also the development of fine motor dexterity required to maneuver the echocardiographic probe. For many CFs who have studied basic cardiac anatomy and physiology during previous training, the failure to attain this dexterity has limited their
Friedman tests.

on the written examination

(B)

had not participated in the boot camp.

independently and obtained echocardiograms of higher quality

had participated in the boot camp obtained more echocardiograms

jority of measured objectives. Furthermore, we found that CFs who

self-efficacy assessments, and scored satisfactory or greater on the ma-

ence in performing echocardiography who completed the boot

participate in performing echocardiographic examinations during

the day while on their echocardiography rotations and while on call

in the hospital. We found that CFs with minimal to no prior experi-

The true efficacy of such an intervention is measured by the capacity

of the learners to retain skills and knowledge that they gain through

participation in this course. Data indicate that presenting a large

of the learners to retain skills and knowledge that they gain through

fellowship training program is one of the largest in the country, the study

term retention of knowledge and skills. Although our cardiology fel-

that the boot camp, coupled with the continued training inherent in

the established curriculum, will enhance medium-term and long-

of cardiology fellowships across the country. This is the first

Short, introductory courses in echocardiography exist at a handful

of the field of medical education.

Although there was a significant increase in written scores and scores of self-efficacy, we did not find a significant correlation between postcamp self-efficacy scores and PBT or written examination scores. Although our study was underpowered to detect such a difference, self-efficacy does not always reflect immediate improvement in performance. At our institution, overnight or weekend echocardiography is often performed by a CF, if the fellow on call is comfortable performing the study. Otherwise, echocardiography is performed by the on-call sonographer, the on-call attending physician, or some combination of the three. The first opportunity to perform an echocardiographic examination is granted to on-call CFs, to provide them with opportunities to learn and practice echocardiography. The finding that CFs who completed the boot camp performed more echocardiographic examinations independently through the first 3 months of fellowship is likely indicative of increased self-efficacy in echocardiography. It is plausible that as CFs who completed the boot camp progress through fellowship, they will be more likely to perform echocardiographic examinations, receive structured feedback on their performance, and further enhance their acquisition of skills. The role of deliberate practice on retaining and enhancing clinical skills has been repeatedly demonstrated.

In this way, we expect CFs to actively experiment with prior echocardiographic experiences and with conceptual knowledge to supplement reflective learning. Therefore, in our program, improving self-efficacy in performing echocardiography is instrumental to preparing CFs to learn echocardiography.

Although didactic lectures may stimulate learners to seek out opportunities to learn about particular subjects, they do not play a significant role in immediately affecting physicians’ performance. Short, introductory courses in echocardiography exist at a handful of cardiology fellowships across the country. This is the first description and analysis of an echocardiography course designed on the principles of experiential learning. The boot camp had a measurable effect on measures of echocardiography knowledge and skill as well as on physicians’ performance, in that CFs who completed the boot camp performed more independent echocardiographic examinations within the first 3 months of fellowship. Ultimately, the goal of medical education is to provide improved patient outcomes. As such, a goal of pediatric cardiology training programs is to graduate cardiologists who provide timely, accurate diagnostic information. As our cohort of CFs progresses through fellowship and ultimately graduates, we hypothesize that increased performance of echocardiographic examinations will translate into improved diagnostic accuracy.

Limitations

Our study had several limitations. Primarily, this study was focused on the feasibility and short-term effects of the educational intervention. The true efficacy of such an intervention is measured by the capacity of the learners to retain skills and knowledge that they gain through participation in this course. Data indicate that presenting a large amount of material without further spaced education is inefficient and results in lower retention of information.

Our hypothesis is that the boot camp, coupled with the continued training inherent in the established curriculum, will enhance medium-term and long-term retention of knowledge and skills. Although our cardiology fellowship training program is one of the largest in the country, the study is underpowered to detect subtle differences in prior experience with echocardiography or cardiology. No CF had more than minimal prior experience with echocardiography. As such, it was not possible to

Figure 3 Precamp and postcamp scores of self-efficacy (A) and on the written examination (B). Groups were compared using Friedman tests.

initial progress in echocardiography. Many cardiologists will attest to the steep learning curve associated with the first few months of performing echocardiography.

Proficiency in performing echocardiography is clearly not attained after a 3-day course. Our goal was to accelerate the acquisition of skills required to perform a basic echocardiographic examination. We attempted to provide CFs with a boost up the learning curve, such that they begin cardiology fellowships with the ability to effectively participate in performing echocardiographic examinations during the day while on their echocardiography rotations and while on call in the hospital. We found that CFs with minimal to no prior experience in performing echocardiography who completed the boot camp had improved scores on written examinations, had improved self-efficacy assessments, and scored satisfactory or greater on the majority of measured objectives. Furthermore, we found that CFs who had participated in the boot camp obtained more echocardiograms independently and obtained echocardiograms of higher quality through the first 3 months of fellowship compared with CFs who had not participated in the boot camp.

The ability to learn complex tasks is linked to learners’ perceptions of their efficacy in learning and performing the tasks, particularly in

Copyright © 2007 American Society of Echocardiography
detect the effect of prior experience with echocardiography on the efficacy of the boot camp. Similarly, the correlation between self-efficacy assessments and performance on the PBT and written evaluations was limited. Although the call structure and curriculum of the cardiology fellowship was kept fairly consistent between the years prior and subsequent to the implementation of the boot camp, there were factors that changed beyond our control, including the total number of CFs. The opportunity to perform an on-call echocardiographic examination has historically been given to the first-year CF on call. Although this did not change from the year before and to the year after institution of the boot camp, it is possible that on-call sognographers or attending physicians were more likely to expect that those who had completed the boot camp would be able to perform echocardiographic examinations independently. The indications and settings surrounding echocardiography performed independently by CFs during fellowship were different from those provided during the boot camp. Despite these differences, we feel that the differences in the number and quality of independent echocardiograms obtained by CFs are an effective measure of the efficacy of the boot camp.

CONCLUSIONS

The pediatric echocardiography boot camp was effective in improving scores on a written examination, self-efficacy assessments in performing pediatric echocardiography, achievement of satisfactory or better scores on a majority of measured objectives, and the number and quality of echocardiograms independently obtained by CFs. Future directions of study include the effects of the boot camp on medium-term and long-term retention of knowledge and skills and the use of ultrasound boot camps in other pediatric subspecialties.

REFERENCES