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Original Research

Implementation of a Self-guided Focused Cardiac Ultrasound Curriculum for Anesthesiology Residents

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Introduction

Point-of-care ultrasound (PoCUS) is one of the fastest growing areas of ultrasound, specifically in emergency medicine, anesthesiology, and critical care medicine. PoCUS is defined as *ultrasonography brought to the patient and performed by the provider in real time*.[1] The ultrasound exam is interpreted in real time and then integrated into clinical decision-making. Within anesthesiology, real-time ultrasound guidance for vascular access and peripheral nerve blocks is widely practiced and considered standard of care at many institutions.[2] Currently, diagnostic ultrasound modalities are becoming more widespread within anesthesiology and critical care medicine.

One such diagnostic modality is point-of-care surface cardiac ultrasound, otherwise known as focused cardiac ultrasound (FoCUS). The American Society of Echocardiography defines FoCUS as a *focused examination of the cardiovascular system performed by a physician by using ultrasound as an adjunct to the physical examination to recognize specific ultrasonic signs that represent a narrow list of potential diagnoses in specific clinical settings*.[3] This information is integrated with other clinical data to guide real-time clinical decisions.

Over the past several years in anesthesiology, there has been increased interest in ultrasound education and more specifically in FoCUS training.[4-12] However, FoCUS curricula can be associated with a significant time investment by ultrasound faculty. Our aim was to create a weeklong curriculum using online didactics, transthoracic echocardiography (TTE) simulation, and image/image interpretation storage software. Our goal was to implement a largely self-guided curriculum to create a consistent educational experience for our residents independent of faculty availability.

We hypothesized that the implementation of a newly designed FoCUS curriculum in the postanesthesia care unit (PACU) would have a positive impact on anesthesiology residents. Specifically, we assessed the curriculum's impact by Kirkpatrick level 1, reaction and opinion; Kirkpatrick level 2, acquisition of knowledge and skills; and Kirkpatrick level 3, application of learning.[13]

Material and Methods

Study Population

The study was approved by the Partners Healthcare Institutional Review Board and written informed consent was obtained from all subjects. The study population was a cohort of anesthesiology residents who each rotated on a weeklong PACU rotation between September 1, 2017 and August 31, 2018. The study analyzed non–patient-related data from the curriculum. If a resident rotated for more than 1 week during this yearlong period, she or he did not repeat the curriculum. The Standards for QUality Improvement Reporting Excellence 2.0 guidelines were considered when preparing this article.

FoCUS Curriculum

The FoCUS curriculum was developed by two of the authors (L.J.P. and J.R.S.), both certified in perioperative transesophageal echocardiography and both completed an additional 25 hours of category 1 CME specific to PoCUS/TTE. The Miles Eleanor Shore Fellowship was awarded to J.R.S. to develop a PoCUS curriculum in the PACU. This provided 1 day of protected nonclinical time per week for 1 academic year.

The PACU rotation was chosen because FoCUS is often used to provide helpful, timely information for acute perioperative decision making. Furthermore, the low PACU patient census during the early morning allowed us to have protected educational time to complete the various components of the curriculum. The residents were given 1 hour of protected educational time during the morning on each day except Wednesday because of grand rounds. Residents were provided an extra hour on Tuesdays and Thursdays to scan patients in the PACU with our nonphysician cardiac sonographer (L.M.M.). The curriculum design incorporated 3 core components essential to FoCUS training: didactics, hands on imaging, and image interpretation and review[3] (see Supplemental Online Material 1).

We used online survey software (REDCap, Nashville, TN) as our educational delivery platform. This method allowed us to automate emailing the curriculum overview and schedule, FoCUS video didactics, quizzes, and questionnaires at specific times throughout the week for residents to com-

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plete during the morning protected time. The software also allowed us to track resident progress and record results and feedback.

Didactics

As described in a review article by Zimmerman and Coker,[14] the FoCUS exam includes 5 views: (1) parasternal long axis, (2) parasternal short axis, (3) apical 4 chamber, (4) subcostal 4 chamber, and (5) subcostal inferior vena cava long axis. For the didactic part of the curriculum, we created 5 educational videos, 6 to 7.5 minutes in length, for each view (subcostal 4 chamber and inferior vena cava were combined). Each video describes how to obtain the view, the anatomy seen in each view, and pitfalls in obtaining the view. Each video also describes the basics of how to assess cardiac function such as signs of decreased left ventricular function, hyperdynamic function, regional wall motion abnormalities, and right heart strain. A fifth video was created as an introduction to the online ultrasound image storage software. To support different learning styles, we also advised residents to read relevant journal articles during their protected hour (see Supplemental Online Material 2 and 3).

Quizzes and Questionnaires

Precurriculum and postcurriculum, the residents were emailed questionnaires regarding their overall experience, comfort level with FoCUS, and the importance of learning PoCUS (Kirkpatrick level 1).

Multiple-choice tests were emailed on the Monday and Friday of each week to assess for knowledge improvement (Kirkpatrick level 2). There were 10 different questions in each quiz, which tested knowledge on image acquisition, probe manipulation, and anatomy identification for the basic FoCUS views. Expanded answers were provided after quiz completion to support resident learning.

The quizzes and questionnaires were designed to each take approximately 5 to 10 minutes to complete and included the following: (1) precurriculum questionnaire, (2) beginning of week quiz (pretest), (3) end of week quiz (posttest), and (4) postcurriculum questionnaire.

Hands-on Training/Simulation

Simulation training has been shown to be an effective educational method for teaching ultrasound skills to anesthesiologists[15] and compares favorably to didactic lectures.[16] Our residents used the Vimedix 2.0 simulator (CAE Healthcare, Sarasota, FL), which gives real-time anatomical feedback to help learners identify and optimize probe positioning for FoCUS views. This TTE simulator is located in and maintained by our hospital's simulation center. There is also a function that enables learners to view abnormal cardiac pathology such as decreased left ventricular function, pericardial effusion, and right ventricular strain. The simulation center staff provided the residents a brief tutorial on how to use the simulator. There were three simulation sessions during the week (see Supplemental Online Material 1): (1) simulator exam administered on day 1 by a nonphysician cardiac sonographer to obtain the 5 FoCUS views that were timed, graded on quality, and had prompts to identify pertinent anatomical structures; (2) self-guided midweek session to optimize image acquisition skills and load cardiac pathologies, as mentioned above; (3) the same simulator exam, mentioned above, administered on the last day. Improvement in skill acquisition (Kirkpatrick level 2) was assessed by the delta in time to image acquisition between the 2 simulator exams and any change in image quality or accuracy of anatomical identification.

On Tuesdays and Thursdays, an extra hour was spent scanning patients in the PACU with a nonphysician cardiac sonographer. These studies, along with the resident's interpretations, were stored on the image software program QPath (Telexy, Maple Ridge, BC, Canada) and emailed to one of the authors (either L.J.P. or J.R.S.). Either one of these individuals, having experience in echocardiography as detailed above, reviewed the exam and emailed feedback to the resident on image quality and interpretation. There was a standardized feedback form created on the QPath software, and each of the aforementioned authors reviewed approximately half the exams.

Statistical Analysis

Paired, within-resident changes in perception of the importance of learning PoCUS, reported comfort level with FoCUS, FoCUS knowledge test score, and FoCUS skills assessment results postcurriculum versus precurriculum are reported as median changes followed by 95% confidence intervals (CIs) reported as ranges. The CIs were calculated based on the normal approximation method with a continuity correction. Paired postcurriculum versus precurriculum responses and measurements were compared using 2-sided Wilcoxon signed-rank tests with no correction for multiple testing. A P value of <.05 was considered statistically significant. Clinical significance was evaluated based on effects size corresponding 95% CI. An *a priori* power analysis for detecting differences in outcomes was not performed because the goal of this study was to assess feasibility, not effectiveness, of the curriculum. Statistical analyses were performed with SAS software version 9.4 (SAS Institute, Cary, NC) and R software version 3.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

The final cohort consisted of 41 residents; 9 residents completed two 1-week rotations in the PACU and therefore only the curriculum once. Secondary to timing of institutional review board approval, 21 residents were enrolled retrospectively and 20 were enrolled prospectively. Most residents had previously performed 6 to 10 FoCUS exams for educational purposes (49%) and 6 to 10 FoCUS exams for guiding clinical decision-making (63%).

Resident Evaluation of Curriculum (Kirkpatrick Level 1)

Residents reported high median [first quartile, third quartile] perceived importance of learning perioperative ultrasound both before (89 [80, 100]) and after (93 [80, 99]) completing the curriculum (median within-participant change: 0 [−9, 7], n = 23, P = .936). A similar pattern was observed for perceived importance of having formal perioperative ultrasound training in residency (median within-participant change: 0 [−9, 8], n = 23, P = .811; Table 1). Reported comfort level with acquiring basic views of a FoCUS exam improved within resident by a median 30 ([26, 45], P = <.001) points precurriculum to postcurriculum, while reported comfort level with interpreting

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the basic views of a FoCUS exam improved within resident by a median 22 ([26, 45] n = 29, P = <.001) points (Table 1). All residents who provided opinions postcurriculum (n = 19) strongly agreed that the curriculum should be permanent, and that perioperative ultrasound is a relevant skill, while 68.4% of residents strongly agreed that the curriculum provided motivation to further learn about perioperative ultrasound (Table 2).

Knowledge and Skills Assessment (Kirkpatrick Level 2)

The same simulator exam was administered on the first and last day of the curriculum to assess the curriculum's impact on image acquisition skills. For all five FoCUS views, there were notable median within-resident decreases in simulator image acquisition times postcurriculum versus precurriculum (Table 3, Figure 1). However, no differences were detected in median change in multiple choice test score, anatomy identification, or image quality postcurriculum versus precurriculum (Table 3, Figure 1).

Application of Skills Learned in the Curriculum (Kirkpatrick Level 3)

In the 2 months following completing the curriculum, 47.4% of residents reported performing a FoCUS exam in clinical practice (n = 19; Table 4). Common indications included hypotension (87.5%) and new electrocardiogram change (37.5%) (n = 8; Table 4). Common effects on clinical management were to confirm a suspected diagnosis (75%), guide fluid management (75%), and guide hemodynamic management (75%) (n = 8; Table 4).

Cost Analysis

Faculty time commitment: The time involved in setting up this curriculum was covered by the Miles Eleanor Shore Fellowship, which supported one nonclinical day per week for 1 year. Once the curriculum was running, faculty time commitment consisted of reviewing the 4 studies obtained by each resident per week and emailing feedback. We estimate approximately 20 minutes per study to review images and provide feedback for a total of 1 hour 20 minutes of faculty time per week.

Sonographer time commitment: Time commitment for our cardiac sonographer consisted of an hour for hands-on scanning on Tuesdays and Thursdays, and an extra 30 minutes on Mondays and Fridays to administer the precurriculum and postcurriculum simulator tests.

Simulation costs: Buying a new ultrasound simulator, similar to the one used in this study, can cost around \$40 000-\$80 000 depending on which pathology packages are chosen to be included. We had access to a TTE simulator already present and maintained by our institution's simulation center.

Ultrasound image storage costs: QPath, a web-based ultrasound exam storage and viewing software, was purchased for an initial license cost of \$20 000 and thereafter an annual maintenance cost of \$1500.

Survey delivery software costs: We had access to REDCap through our institution; therefore, it was free of cost for us.

Discussion

This study examines the implementation of our FoCUS curriculum used by 41 anesthesiology residents rotating in the PACU. Interesting findings include favorable evaluation from the residents (Kirkpatrick level 1) and improvement in image acquisition skills by objective measures (Kirkpatrick level 2). More specifically, we observed an increased perceived comfort level to acquire and interpret FoCUS views (Table 1) as well as decreased image acquisition time (in some views over a 50% reduction; Table 3, Figure 1).

As PoCUS continues to evolve as an important clinical tool, our specialty will need to standardize training pathways for trainee and graduate anesthesiologists.[17] The updated 2018 Accreditation Council for Graduate Medical Education program[18] requirements for anesthesiology contain competency criteria that include the following: *using surface ultrasound and transesophageal and transthoracic echocardiography to guide the performance of invasive procedures and to evaluate organ function and pathology as related to anesthesia, critical care, and resuscitation*. However, there are currently no anesthesia-specific criteria for assessing resident competency in FoCUS. Emergency medicine is a specialty that incorporates FoCUS into residency training, stipulating that each resident should perform 50 supervised studies to be deemed competent in basic cardiac ultrasound. Our hope is that the knowledge and skills developed during this 1-week PACU FoCUS curriculum will set our residents on the path to obtain the imaging numbers required achieve competency over the duration of their residency. Moving forward, we will need to determine as a specialty what constitutes competency in the use of FoCUS.

In 2015, Ramsingh et al[19] published positive results from the implementation of a comprehensive ultrasound curriculum for anesthesia residents. Of note, their 2-year program consisted of weekly 1-hour sessions for the Year 1 participants and monthly 2.5-hour sessions for their Year 2 participants. In addition, departmentally funded nonclinical time was provided for 4 ultrasound faculty to support an ultrasound attending for each day of the week.[19] This amount of dedicated time and departmental support is not feasible at many institutions, although the need for an effective ultrasound training program is just as real. We therefore report the development and implementation of our novel self-guided FoCUS curriculum that harnesses innovative educational techniques to provide a high-quality, consistent experience while minimizing the time commitment from clinical faculty.

In terms of faculty time commitment, once our curriculum was up and running, we estimate faculty time commitment of 1 hour 20 minutes per week. There was, however, significant upfront time investment to obtain further training in PoCUS, create the video didactic series, quizzes, and develop reliable automation of curriculum delivery via email. Programs looking to adopt a similar curriculum could use available free, high-quality online resources rather than recreating their own, thereby significantly cutting down on this time investment. Also in terms of the applicability of this curriculum to other institutions, we were very fortunate to have access to a cardiac sonographer. Understandably, this resource may not be available in other departments.

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TTE simulator access is another limited resource at other institutions and warrants consideration when developing a FoCUS curriculum.

There were several limitations with this study. The decision was made to publish our experience of creating and implementing this curriculum partway through the year after it launched. Therefore, we obtained retrospective consent from half our residents to use the data we collected during their PACU rotation for this article. Although this did not affect the way in which each resident was assessed at the end of each rotation, how their data was collected, or which residents were scheduled to rotate in the PACU, the fact that only half our residents were in enrolled in a prospective manner represents a significant limitation in how our results may be interpreted.

We did not control for previous FoCUS experience predating the curriculum. This PACU curriculum represents one component of our longitudinal ultrasound education program for residents. This may have resulted in varying benefits between residents with more or less prior exposure to FoCUS. Additionally, we did not control what rotations the residents completed in the 2 months after the PACU rotation, where opportunities to perform a FoCUS exam may have differed.

While required to complete this educational curriculum as part of the PACU rotation, there were varying degrees of completion for unknown reasons. For example, in some instances, the postweek evaluation questionnaire or postweek simulation exam was not completed. Therefore, we could not compare the prequestionnaire and simulation results for that individual. Possible contributing factors affecting curriculum completion were as follows: (1) unavailability of the cardiac sonographer who also had responsibilities on the intraoperative transesophageal echocardiography service; (2) unexpected early in the day high PACU census, making it difficult to perform an educational FoCUS exam; and (3) technical glitches with our educational delivery platform. We also do not know if the individual spent more than the expected time reading other resources outside of the curriculum or completed more than the anticipated number of FoCUS exams. These factors may have affected the degree of impact the curriculum had on the individual resident. Finally, the experts reviewing ultrasound studies performed by the residents on patients did not compare scoring systems, and therefore there may have been variation in both feedback given and what standard constituted an *adequate* exam.

In summary, our study suggests that the implementation of a weeklong self-guided FoCUS curriculum had a positive impact on anesthesiology resident rotating in the PACU. We documented increased perceived resident comfort level in acquiring and interpreting FoCUS views and decreased image acquisition time (in some views, over 50% reduction). In the future, a larger prospective trial is warranted to evaluate this curriculum and the value of FoCUS.

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Abstract

Background: Focused cardiac ultrasound (FoCUS) is an increasingly used diagnostic modality for anesthesiologists and intensivists. However, training residents in its use can be resource intensive. We investigated the feasibility of implementing a self-guided FoCUS curriculum for anesthesiology residents rotating in the postanesthesia care unit (PACU).

Methods: We created a FoCUS curriculum with the aim of providing a consistent largely self-guided experience that would improve FoCUS knowledge and skills while minimizing ongoing time commitment from faculty. To achieve this, we used several methods: (1) developed video didactics and quizzes; (2) used an online educational delivery platform to automate delivery of educational content, monitor resident progress, and elicit feedback; (3) used the transthoracic echocardiography simulator for aided hands-on learning; (4) dedicated educational time that integrated into PACU workflow; (5) worked with a cardiac sonographer; and (6) used image storage software to facilitate remote feedback by ultrasound faculty. The response to the curriculum was evaluated using Kirkpatrick levels 1-3.

Results: Forty-one anesthesiology residents rotated through the PACU over a 1-year period and completed this weeklong self-guided FoCUS curriculum. Interesting findings include: (1) favorable evaluation from the residents and (2) improvement in image acquisition skills by objective measures. Once the curriculum was established, ongoing faculty time commitment was approximately 1 hour 20 minutes per week.

Conclusions: The implementation of a FoCUS curriculum in the PACU resulted in favorable resident evaluation and improved FoCUS skills. The curriculum was feasible and self-sustainable because of the novel educational approach employed.

Keywords: Point of care ultrasound, focused cardiac ultrasound, anesthesiology education

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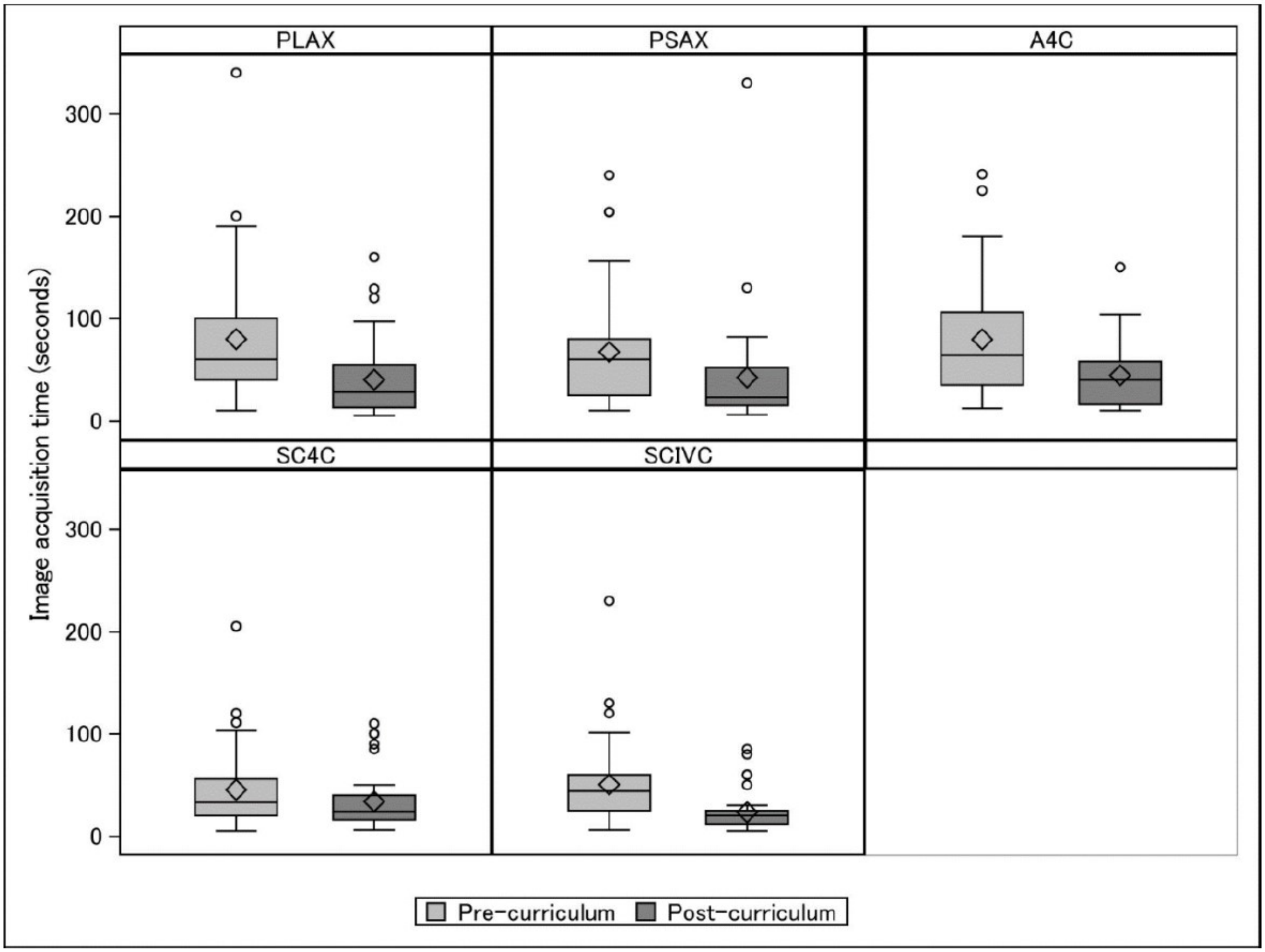
Figure

Figure 1. *Boxplots of precurriculum and postcurriculum image acquisition times. Boxes consist of the first quartile, median, and third quartile. The whiskers extend to the most extreme observations within 1.5 times the interquartile range below and above the first and third quartiles, respectively. Diamonds represent mean values and circles indicate outliers. PLAX = parasternal long axis; PSAX = parasternal short axis; A4C = apical 4 chamber; SC4C = subcostal 4 chamber; SCVIVC = subcostal inferior vena cava.*



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Tables

Table 1. *Within Resident Change in Perceptions of Perioperative Ultrasound and Hands on Skill Set*

	N	Precurriculum[a]	Postcurriculum[a]	Within-Resident Change	
		Median (Q1, Q3)	Median (Q1, Q3)	Median (95% CI)[b]	*P* Value[c]
How important is learning perioperative ultrasound in anesthesiology training?	23	89 (80, 100)	93 (80, 99)	0 (−9, 7)	.936
How important is it to have a formal perioperative training in anesthesiology residency?	23	89 (82, 96)	90 (82, 100)	0 (−9, 8)	.811
Comfort level to acquire the views of a FoCUS exam	29	40 (21, 50)	72 (70, 80)	30 (26, 45)	<.001
Comfort level to interpret the views of a FoCUS exam	29	41 (24, 54)	70 (54, 71)	22 (17, 32)	<.001

Abbreviations: CI, confidence interval; FoCUS, focused cardiac ultrasound; Q1, first quartile; Q3, third quartile.

[a] Precurriculum and postcurriculum scores are based on a 100-point scale and are expressed as median values. These questions were asked at the start and completion of the curriculum.

[b] 95% confidence intervals for median within-resident change in responses postcurriculum versus precurriculum were calculated based on normal approximations with a continuity correction.

[c] = Paired postcurriculum versus precurriculum responses were compared using Wilcoxon signed-rank tests.

Table 2. *Postcurriculum Opinions of Perioperative Ultrasound, N = 19*

	n (%)
The curriculum should continue as a permanent part of the resident education experience	
Strongly agree	19 (100)
Perioperative ultrasound is a relevant skill for future anesthesiologists	
Strongly agree	19 (100)
The curriculum has motivated me to further learn about perioperative ultrasound	
Somewhat agree	6 (31.6)
Strongly agree	13 (68.4)

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Table 3. *Residents' Performance on Multiple Choice and Simulation Tests*

	N	Precurriculum	Postcurriculum	Change	
		Median (Q1, Q3)	Median (Q1, Q3)	Median (95% CI)[a]	*P* Value
Multiple choice test score	41	6 (5, 8)	7 (5, 8)	1 (−1, 2)	.259
Image acquisition time (sec)					
PLAX	37	60 (40, 100)	28 (13, 55)	−33 (−56, −21)	<.001
PSAX	37	60 (25, 80)	23 (15, 52)	−14 (−39, −10)	<.001
A4C	37	64 (35, 106)	40 (16, 58)	−29 (−50, −17)	<.001
SC4C	37	33 (20, 56)	24 (16, 40)	−9 (−22, −1)	.036
SCIVC	37	44 (25, 60)	20 (12, 25)	−15 (−35, −15)	<.001
Anatomy identification (% correct)					
PLAX	28	88 (88, 88)	88 (88, 88)	0 (−38, 13)	.832
PSAX	29	100 (63, 100)	100 (63, 100)	0 (−38, 44)	.813
A4C	29	75 (75, 75)	75 (75, 75)	0 (−75, 13)	.280
SC4C	29	75 (75, 75)	75 (75, 75)	0[c]	.174
SCIVC	29	38 (38, 38)	38 (38, 38)	0[c]	.174
Image quality[b]					
PLAX	37	2 (2, 2)	2 (2, 2)	0 (−1, 0)	.618
PSAX	37	2 (2, 2)	2 (1, 2)	0 (−1, 0)	.035
A4C	37	2 (2, 2)	2 (2, 2)	0 (−1, 0)	.336
SC4C	37	2 (1, 2)	2 (1, 2)	0 (−1, 1)	.829
SCIVC	37	2 (1, 2)	2 (1, 2)	0 (−1, 0)	.433

Abbreviations: A4C, apical 4 chamber; CI, confidence interval; FoCUS, focused cardiac ultrasound; PLAX, parasternal long axis; PSAX, parasternal short axis; Q1, first quartile; Q3, third quartile; SC4C, subcostal 4 chamber; SCIVC, subcostal inferior vena cava.

[a] = 95% CIs for median within-resident change in responses postcurriculum versus precurriculum were calculated based on normal approximations with a continuity correction.

[b] = Image quality graded on 1-4 point scale, with *1* being *highest quality* and *4* being *lowest quality*.

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Table 4. *Postcurriculum Application of Focused Cardiac Ultrasound (FoCUS) Into Clinical Practice*

	N	n (%)
Performed clinical FoCUS exam within 2 month period after curriculum	19	9 (47.4)
Number of FoCUS exams performed	19	
Not reported		1 (5.3)
0		10 (52.6)
1		1 (5.3)
2		1 (5.3)
3		1 (5.3)
4		2 (10.5)
5		3 (15.8)
FoCUS exam indication[a]	8	
Hypotension		7 (87.5)
Electrocardiogram		3 (37.5)
Congestive heart failure		2 (25.0)
Chest pain		1 (12.5)
Cardiac arrest		1 (12.5)
FoCUS exam effect on clinical management[a]	8	
Confirm suspected diagnosis		6 (75.0)
Guide fluid management		6 (75.0)
Guide hemodynamic management		6 (75.0)
New diagnosis		1 (12.5)
Patient triaged to higher level of care unit		1 (12.5)
Insertion of chest tube		1 (12.5)
Rule out diagnosis and discharge home		1 (12.5)

[a] Participants could select more than 1 answer.

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Supplemental Online Material 1

Supplemental Online Material 1

FoCUS Curriculum in the PACU

Monday

- 8-8:30 am
  - Complete simulation exam with Lindsey Molloy
- 8:30-9 am
  - Complete questionnaire
  - Complete pretest exam
  - Read Zimmeran, A+A 2017 on Focused Cardiac Ultrasound
    - https://www.dropbox.com/s/o0baec02cvzx5ww/FOCUS%20Review_AA%203-17.pdf?dl=0

Tuesday

- 8-9 am
  - Watch online lectures on "Parasternal Long Axis," "Parasternal Short Axis," "Apical 4 chamber," "Subcostal 4 chamber, and IVC."
  - Watch "Introduction to QPath"
- 9:30 am or 10 am
  - Perform 1-2 FoCUS exams on clinically stable patients
  - On QPath
    - Fill out worksheet for both exams
    - Submit for QA to either Jeff Swanson or Louisa Palmer

Thursday

- 8-8:30 am
  - Read Focused Cardiac ultrasound guideline paper, *JASE* 2013
    - https://www.dropbox.com/s/svyy4r8xuc0luda/J_Am_Soc_Echocardiogr_2013_Spencer.pdf?dl=0
- 8:30-9 am
  - STRATUS (self-guided)
    - Obtain 5 FoCUS views on normal and the following pathologies: biventricular dysfunction, pericardial tamponade, left ventricular systolic dysfunction, anterior MI. Understand how to optimize views with subtle probe maneuvers.
- 9:30 am or 10 am
  - Perform 1-2 FoCUS exams on clinically stable patients
  - On QPath:
    - Fill out worksheet for both exams
    - Submit for QA to either Jeff Swanson or Louisa Palmer

Friday

- 8-8:30 am
  - Complete posttest exam
  - Fill out online evaluation form
- 8:30-9 am
  - Complete simulation exam with Lindsey Molloy

Abbreviations: MI, myocardial infarction; PACU, postanesthesia care unit; QA, quality assurance.

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Supplemental Online Material 2

CME

The Nuts and Bolts of Performing Focused Cardiovascular Ultrasound (FoCUS)

Josh M. Zimmerman, MD, FASE,* and Bradley J. Coker, MD†

The benefit of focused cardiovascular ultrasound as an adjunct to physical examination has been shown in numerous specialties and in diverse clinical settings. Although the value of these techniques to the practice of anesthesiology is substantial, they have only begun to be incorporated. This article reviews the basic techniques required to perform a bedside focused cardiovascular ultrasound (ie, FoCUS examination). This includes a discussion of patient positioning, breath control, probe position, and manipulation and was supplemented by normal and abnormal examples for review. (Anesth Analg 2017;124:753–60)

This article reviews the basic techniques required to perform a focused cardiovascular ultrasound (FoCUS) examination at the bedside. It begins with indications, limitations, and equipment, then describes in detail the nuts and bolts of physically performing the examination. For each of the views, there is a discussion of patient positioning and technique, a brief review of anatomy, and examples of normal and abnormal images. This article is also accompanied by a Supplemental Video tutorial that demonstrates the techniques described herein (Supplemental Digital Content, http://links.lww.com/AA/B686). Obviously, no article is adequate to train a provider without a background in cardiovascular ultrasound. The goal of this article is not to provide comprehensive education but rather a solid introduction and reference for further practice. A broader description of the history, application, value, and training required for anesthesiologists to perform these techniques has been published separately.

FoCUS should be seen as an extension of the physical examination rather than as a limited version of a comprehensive echocardiogram. When viewed in this light, ultrasound can expand dramatically the diagnostic potential of the bedside evaluation. Although there are numerous potential reasons to perform FoCUS, the most common indications in the perioperative period include signs or symptoms of heart failure and hemodynamic instability. The diagnostic targets of FoCUS include evaluation of cardiac structure, biventricular systolic function, valvular function, pericardial effusion, and volume status.

It is important that physicians performing FoCUS have a clear understanding of the limitations inherent to the techniques, as well as the limitations of their individual level of skill, training, and experience. Furthermore, the pocket-sized devices often used for FoCUS cannot be expected to have the same image quality and resolution of a full-service platform. The FoCUS examination is neither comprehensive nor designed to make quantitative assessments.[1] Subtle abnormalities may be overlooked, and there may be uncertainty regarding the severity of abnormalities that are identified. There is a natural tendency to place a high value on what can be seen, and the practitioner of FoCUS needs to be careful to neither lock in nor exclude diagnoses based on limited ultrasound information. The findings of an examination always should be taken in context, with a healthy suspicion that the interpretation could be flawed or incomplete and with a low threshold to request a second opinion or a formal echocardiogram to confirm findings.

EQUIPMENT AND ULTRASOUND PROBE SELECTION

Focused ultrasound can be performed with any of a variety of ultrasound machines, from the stand-alone full-service echocardiography platforms, to smaller portable machines, to the smallest pocket-sized ultrasound devices. It is not the type of machine that defines focused ultrasound but the training of the provider and the scope of the clinical questions being addressed. Any ultrasound system can be used so long as it meets the following requirements: availability of a 2-dimensional phased array (cardiac) probe of appropriate frequency for adult patients; the ability to record date, time, and patient identifiers with the images; and the ability to adjust gain and depth. The availability of M-mode, color flow Doppler, spectral Doppler imaging, and measurement tools are not required for a FoCUS examination.[1,2] Electrocardiogram (ECG) capability is not required for FoCUS, and some machines may not be able to display ECG. When machines with this capability are used, however, ECG leads should be connected to ensure that images are acquired appropriately.

ULTRASOUND PROBE TERMINOLOGY

Because the language used to describe ultrasound probe manipulation is not standardized, the terminology used in this article needs to be defined. For cardiac ultrasound, the probe is held in the left hand so that the right hand can be used to manipulate the machine. All probes will have an indicator, generally a light or a notch, that corresponds to an orientation marker, usually a dot, on the ultrasound image. For cardiac ultrasound, the orientation marker is on

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the right of the ultrasound image. Although probe orientation can be confusing for new bedside ultrasonographers, it need not be. The ultimate goal is to create the correct orientation on the screen. If the image appears reversed, simply rotate the probe 180°. When describing probe motion, the authors will use the following terminology:

Sliding. Motion of the probe to a different position on the body. This will also be described as "window shopping." This is done to find the optimal position from which to image, particularly when trying to scan between ribs. The sliding motion can be done to move from one interspace to another (larger motions), or to optimize imaging at a given interspace (small motions).

Tilting. With the probe kept at the same location on the body, a rocking motion is applied to the probe to image different structures within the same plane (Figure 1). This is done most commonly to center an image on the screen and represents a motion of the "tail" or cord of the transducer toward or away from the probe's indicator.

Angulation. With the probe kept at the same location on the body, the transducer is moved side-to-side to create new imaging planes relatively parallel to the original plane. This motion will be at angles perpendicular to the tilting motion.

Rotation. With the probe otherwise held still, it is turned around its central axis similar to turning a key in a lock.

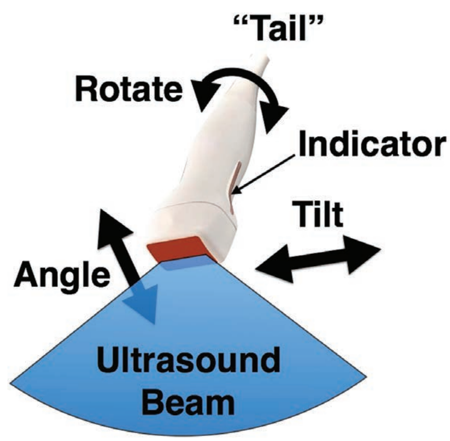

Figure 1. Ultrasound probe manipulation nomenclature. Tilt moves the probe in the plane of the ultrasound beam, angle moves the probe perpendicular to the beam (creating new planes parallel to the original), and rotate turns the probe like a key in a lock.

ULTRASOUND IMAGE TERMINOLOGY

Window. The term window is used to describe the location of the ultrasound probe. Just like a window in a house, this is what the transducer transducer looks through to see the heart. The 3 windows described in FoCUS are parasternal, apical, and subcostal (Figure 2).

Plane. This is the anatomic plane or cross section of the heart that is made by the ultrasound beam. The 3 planes used for the FoCUS examination are the long axis, short axis, and 4 chamber.

1. Long axis: Parallel to the long axis of the left ventricle (LV), simultaneously intersecting the apex of the LV, the center of the aortic valve (AV), and the center of the mitral valve in the anterior–posterior dimension.
2. Short axis: Perpendicular to the long axis of the ventricle, showing a circular cross section of the ventricle. In the case of FoCUS, the LV short axis will be at the level of the papillary muscles.
3. Four chamber: Perpendicular to the short axis, this plane simultaneously transects the apex of the LV, both ventricles and atria, and the mitral and tricuspid valves.

View. A combination of window and plane used to describe a particular image. For instance, the parasternal long-axis (PLAX) view is made from the parasternal window and transects the heart in the long axis plane.

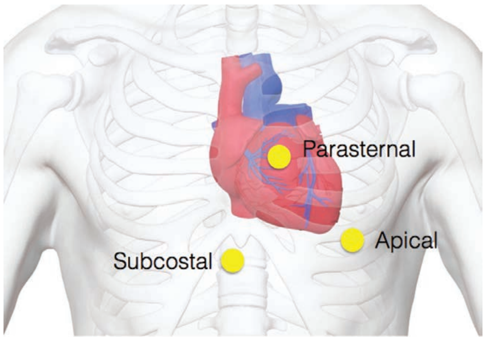

Figure 2. The heart in the chest, with the sternum and ribs to provide orientation. The 3 windows are indicated by the yellow dots.

KNOBOLOGY AND IMAGE OPTIMIZATION

A detailed understanding of ultrasound physics is not necessary for the practitioner of FoCUS; however, some understanding of image optimization will prove useful. The following settings are available on many of the simplest ultrasound devices.

Depth. The depth of scanning for each image should be set to include the structures of interest and nothing else (as shown in the video examples). Inappropriately increasing the depth of scanning both makes relevant structures appear smaller and results in an image that is refreshed less frequently with less temporal resolution and quality.

Gain. This setting affects the displayed brightness of the ultrasound image. Gain should be set so that blood appears black rather than gray. A reasonable setting could be achieved by turning gain up until blood appears gray, then decreasing it slightly.

Time-Gain Compensation. Some ultrasound systems offer the ability to automatically adjust gain to optimize the display and to provide uniform brightness throughout the image rather than an image that becomes darker at increasing depth due to the lower strength of the returned signal. Sometimes

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referred to as the "make it better button," it can be a quick way to improve the gain and image display settings.

PARASTERNAL WINDOW

Patient Positioning. A complete FoCUS examination often can be performed in the supine patient, and clinical situations in which patients cannot be turned will be encountered frequently. Parasternal imaging, however, would ideally be performed in the full left-lateral decubitus position, with the patient's left arm extended. It is often comfortable for patient to rest their left forearms under their head (Figure 3). For all FoCUS imaging, the ultrasonographer should be positioned on the patient's left side with the probe held in the left hand, leaving the right hand free to manipulate the ultrasound machine.

Breath Control. Imaging from every window is better if patients can breathe shallowly. In spontaneously ventilating patients, parasternal images are often best at end-exhalation when there is less lung interposed between the probe and the heart. If possible, having patients briefly hold their breath at a low lung volume can improve imaging from the parasternal window. The authors' technique is to instruct the patient to "Take a deep breath in, now breathe all the way out and hold it…hold it…hold it…now breathe." This reminds the patient not to begin breathing in until adequate images have been obtained. In intubated patients, it can help to briefly pause the ventilator to allow a passive exhalation.

Figure 3. Optimal patient positioning for the parasternal window. The patient is in the left lateral decubitus position with his left arm extended.

Parasternal Long Axis (Supplemental Digital Content, Video 1, http://links.lww.com/AA/B611)

Probe Position and Manipulation. The PLAX image is made with the probe placed just to the left of the sternum in the third to fifth intercostal space with the indicator pointed toward the patient's right shoulder (Figure 4). The technique referred to by the authors as "window shopping" should be used. This entails moving the probe briefly across the left parasternal interspaces to select the one that provides the best image. After identifying the best window, small changes in rotation, tilt, and angle should be made to optimize the image.

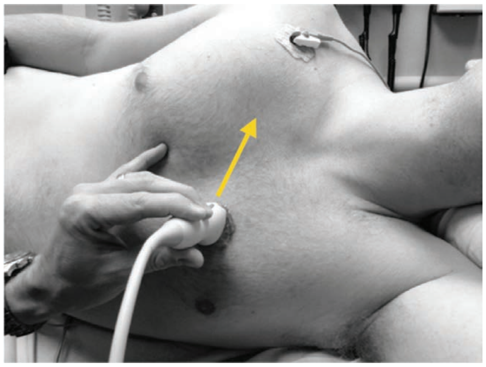

Figure 4. Probe position for the parasternal long axis (PLAX.) The probe is just to the left of the sternum, in the fourth intercostal space (though this location will vary), with the indicator pointing toward the patient's right shoulder. The indicator location and direction is shown by the yellow arrow.

Anatomy. The PLAX shows the right ventricular outflow tract (RVOT), the AV and proximal ascending aorta, the left atrium, mitral valve, and the basal and mid segments of the anteroseptal and inferolateral walls of the LV (Supplemental Digital Content, Video 1, http://links.lww.com/AA/B611; Figure 5).

Assessment. A great deal of valuable information is available from the PLAX image. The authors recommend a consistent approach to evaluating this image, starting with the RVOT and moving clockwise.

1. Right ventricle (RV): Although this image is not the best to quantify the size or function of the RV, the sonographer can get a sense of significant RV enlargement or dysfunction. The RVOT should appear similar in size to the aortic root in this view. As discussed previously, all assessment of chamber size with FoCUS is qualitative but nonetheless valuable.
2. AV: The structure and opening of the AV can be assessed. A valve that opens well, even if calcified, is not likely to have clinically significant stenosis. An AV

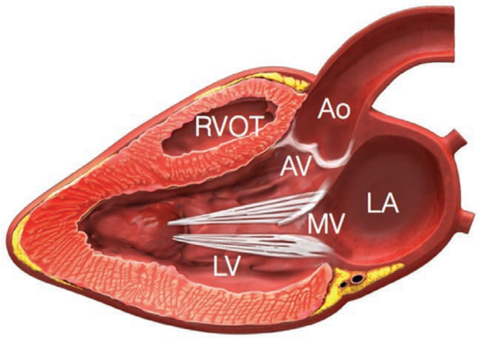

Figure 5. Anatomy of the PLAX. At the top of the screen, closest to the ultrasound probe, is the right ventricular outflow tract (RVOT). Moving clockwise, the aortic valve (AV) and proximal ascending aorta (Ao) are seen, then the left atrium (LA), mitral valve (MV) and left ventricle (LV). PLAX indicates parasternal long axis.

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that is heavily calcified and opens poorly should alert the provider to the possibility of significant aortic stenosis (Supplemental Digital Content, Video 2, http://links.lww.com/AA/B612).

3. Left atrium: A qualitative assessment of left atrial size can be obtained by visually comparing the diameter of the atrium to that of the aortic root. A left atrium that is much larger than the aortic root suggests a history of elevated left atrial pressures (from diastolic dysfunction, mitral valve disease, or atrial fibrillation). (Supplemental Digital Content, Video 2, http://links.lww.com/AA/B612).
4. Mitral valve: A normal mitral valve should open briskly in diastole and should close completely in systole, with no portion of the valve prolapsing above the annulus in this view. Leaflet tissue that extends above the annulus in systole suggests mitral valve prolapse or flail (Supplemental Digital Content, Video 3, http://links.lww.com/AA/B613). An anterior mitral leaflet that does not open briskly and come near the anteroseptal wall in diastole should alert the provider to the possibility of decreased cardiac output or mitral stenosis (Supplemental Digital Content, Video 4, http://links.lww.com/AA/B614). Mitral annular calcification (MAC), particularly at the base of the posterior leaflet, is a common finding in patients with hypertension, vascular disease, and renal failure (Supplemental Digital Content, Video 2, http://links.lww.com/AA/B612). Because MAC affects the base of the valve rather than the coaptation, it is a rare cause of hemodynamically significant stenosis. Rheumatic mitral valve disease, on the other hand, affects the subvalvular apparatus, commissures, and coaptation early in the disease process and creates what is described as a "hockey stick" deformity with stenosis resulting from a much smaller degree of leaflet thickening (Supplemental Digital Content, Video 5, http://links.lww.com/AA/B615). Another important abnormality that can be identified from the PLAX is systolic anterior motion (SAM) of the anterior leaflet of the mitral valve. The identification of SAM should alert the practitioner to the possibility of dynamic left ventricular outflow tract obstruction. This pathology can be seen in hypertrophic cardiomyopathy but also can be seen in patients with small, thick ventricles and abnormal mitral leaflet tissue. The findings can be subtle but should be sought when patients present with hemodynamic instability, syncope, or heart failure symptoms. It should be suspected when a portion of the mitral valve appears to be drawn into the left ventricular outflow tract during late systole (Supplemental Digital Content, Video 6, http://links.lww.com/AA/B616).
5. LV: Although only a portion of the anteroseptal and inferolateral walls are viewed in this image, a good sense of global and regional function can be obtained in the PLAX. There should be brisk thickening of the myocardium in systole. Other qualitative signs of normal global LV systolic function include a brisk anterior–posterior motion of the aortic root caused by the filling and emptying of the LV and LA, brisk opening of the anterior mitral leaflet in diastole, and the descent of the base of the LV toward the apex, representing the piston-like effect of longitudinal myocardial fibers. Decreased global function will be seen as decreased aortic root excursion, decreased excursion of the anterior mitral leaflet, decreased descent of the base of the MV, and decreased thickening of the myocardium (Supplemental Digital Content, Video 4, http://links.lww.com/AA/B614).
6. Effusions: Pericardial effusion can sometimes be identified in this view and can be distinguished from pleural effusion based on the relationship of the fluid to the descending thoracic aorta. A pericardial effusion will come between the aorta and the heart, whereas a left pleural effusion will appear behind the aorta (toward the bottom of the image) (Supplemental Digital Content, Video 7, http://links.lww.com/AA/B617). To ensure that effusion is not overlooked, the sonographer should begin imaging the PLAX with adequate depth to visualize at least 5 cm beyond the descending aorta.

Parasternal Short Axis (PSAX) (Supplemental Digital Content, Video 8, http://links.lww.com/AA/B618)

Probe Position and Manipulation. Starting with the PLAX view, the short-axis image is made by keeping the probe in the same location and rotating 90° clockwise so the indicator points toward the patients left shoulder (Figure 6).

Anatomy. The PSAX view transects the left and right ventricles at the level of the papillary muscles (the mid-portion of the LV). The short-axis section is like slices in a loaf of bread. The mid-segments of each of the 6 ventricular walls can be seen, representing myocardial territories perfused by each of the 3 main coronary arteries (Figure 7).

Assessment. The PSAX gives important information about global and regional ventricular function and filling and is useful particularly in the hemodynamically unstable patient.

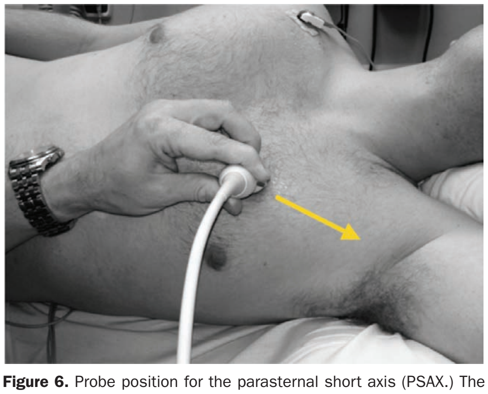

Figure 6. Probe position for the parasternal short axis (PSAX.) The probe is just to the left of the sternum, in the fourth intercostal space (though this location will vary), with the indicator pointing toward the patient's left shoulder. The indicator location and direction is shown by the yellow arrow.

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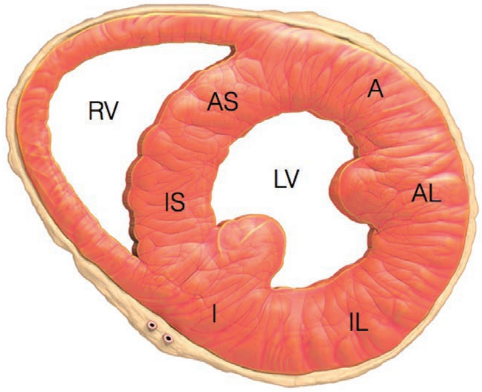

Figure 7. Anatomy of the PSAX. The right ventricle is seen on the left side of the screen and defines the 2 septal walls of the left ventricle. The papillary muscles are seen, identifying this as the midportion of the ventricle. Six segments of the ventricle are shown, representing distributions of all 3 coronary arteries. A, mid-anterior segment of the LV; AL indicates mid-anterolateral segment of the LV; AS, mid-anteroseptal segment of the LV; I, mid-inferior segment of the LV; IL, mid-inferolateral segment of the LV; IS, mid-inferoseptal segment of the LV; LV, left ventricle; PSAX, parasternal short axis; RV, right ventricle.

1. LV: In a ventricle with normal regional function, the PSAX will have symmetrical thickening of each of the myocardial segments. Decreased thickening (hypokinesis) or absence of thickening (akinesis) suggests coronary ischemia or infarction. Typically, the left anterior descending coronary artery perfuses the anterior portion of the LV, the circumflex coronary artery perfuses the lateral portion of the ventricle, and the right coronary artery perfuses the inferior portion of the ventricle (Supplemental Digital Content, Video 9, http://links.lww.com/AA/B619). In hypovolemic states, the LV will appear relatively small in diastole with hyperdynamic systolic function (Supplemental Digital Content, Video 10, http://links.lww.com/AA/B620). In low afterload states, the ventricle will be fuller in diastole but will still be empty in systole reflecting increased cardiac output (Supplemental Digital Content, Video 11, http://links.lww.com/AA/B621).
2. Right ventricle: The right ventricle is not the focus of the PSAX, but if it appears significantly larger than the LV, it should trigger further evaluation of the RV from the apical 4 chamber.
3. Interventricular septum (IVS): The behavior and position of the IVS can give important information about the balance of pressures in the two ventricles. Normally the LV appears circular throughout the cardiac cycle, reflecting the fact that LV pressures are higher than RV pressures. If the IVS is flat in diastole but returns to normal (concave to the LV) in systole, it suggests an RV volume overload state (often tricuspid regurgitation.) If the IVS stays flattened throughout systole and diastole, it suggests a pressure overload state of the RV.[3] Septal flattening in systole is an ominous sign that is often seen in severe pulmonary hypertension (Supplemental Digital Content, Video 12, http://links.lww.com/AA/B622).

APICAL WINDOW

Patient Positioning. Like the parasternal window, the apical window is best imaged with the patient in the left lateral decubitus position. Apical images are often more challenging than parasternal images when performed in the supine position and even a small amount of left tilt of the patient can improve the images. This can be achieved in some cases by a towel or pillow bump under the right side of the patient. With the patient in the full left-lateral decubitus position, it can be challenging to place the ultrasound probe at the true apex. This problem can result in an image with the right ventricle at the apex of the screen, giving the false impression of RV enlargement. This can be overcome either by moving the patient all the way to the edge of the bed or by tipping the patient slightly back from a true left lateral position.

Breath Control. Unlike the parasternal window, the optimal lung volume for apical images is less predictable. The LV apex generally moves slightly caudally as the patient inhales. After finding a reasonable window, the patient can be asked to breathe in or out slowly until the best apical image is achieved. They can then be asked to hold their breath using the same "hold it…hold it…hold it, now breathe" technique described earlier.

Apical 4-Chamber (A4) (Supplemental Digital Content, Video 13, http://links.lww.com/AA/B623)

Probe Position and Manipulation. The A4 image generally is more challenging than the parasternal or subcostal images. The first step is to identify the correct window for imaging. Again, this will involve a degree of window shopping. In some cases, palpation of the point of maximal impulse can be useful, though the authors generally identify the apex with ultrasound alone. The apex is usually just inferior and lateral to the nipple in men, and under the inferolateral quadrant of the left breast in women. Starting slightly medial to the expected location and moving the probe cephalad and caudad over several interspaces while slowly sliding laterally can help identify the apex. For the 4-chamber plane, the probe indicator will be often be pointed to the 5 o'clock position when viewed from above (Figure 8).

Anatomy. The apex of the LV should be at the top of the screen. The inferoseptal and anterolateral walls of the LV can be seen, and 6 myocardial segments (basal, mid-, and apical) can be identified. The longer anterior mitral leaflet can be seen medially with the shorter posterior leaflet laterally. The right ventricle can be seen as well, with the tricuspid valve displaced slightly toward the apex relative to the mitral valve. The left and right atrial should be visualized at the bottom of the image (Figure 9).

Assessment.

1. Left ventricle: This is another excellent view to assess global and regional left ventricular systolic function. A normal ventricle will have symmetrical thickening,

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a brisk opening of the mitral valve, and a brisk descent of the mitral valve toward the LV apex (Supplemental Digital Content, Video 13, http://links.lww.com/AA/B623). Ischemia or infarction of the left anterior descending coronary artery can often be recognized in this view as wall motion abnormalities in the apical portion of the ventricle (Supplemental Digital Content, Video 14, http://links.lww.com/AA/B624).

2. Mitral valve: The leaflets of a normal valve should remain below the mitral annulus with adequate coaptation in systole. Significant prolapse or flail, or an obvious lack of valve coaptation should raise the possibility of significant mitral regurgitation (Supplemental Digital Content, Video 15, http://links.lww.com/AA/B625). MAC and rheumatic valve changes can also be identified, as described in the PLAX assessment (Supplemental Digital Content, Video 2, http://links.lww.com/AA/B612; and Supplemental Digital Content, Video 16, http://links.lww.com/AA/B626).
3. Atria: The relative sizes of the atria can be assessed qualitatively in this view. They should be similar in size and should be not appear larger than the ventricles in diastole (Supplemental Digital Content, Video 16, http://links.lww.com/AA/B626).
4. Right ventricle: This is the preferred view to assess RV size and global systolic function.[3] The RV should appear smaller than the LV in the A4, and the apex of the heart should be made up of only LV. An RV that contributes to the apex or that appears similar in size to the LV in this view is an indication of RV enlargement. A normal RV will have thickening of the free wall and a brisk descent of the base of the tricuspid valve toward the apex in systole (Supplemental Digital Content, Video 17, http://links.lww.com/AA/B627).
5. Tricuspid valve: This is also the preferred view to assess structure and function of the tricuspid valve. A normal TV will open fully in diastole, and will remain below the annulus with good coaptation in systole. The appearance of significant prolapse or a lack of valve coaptation should suggest the presence of significant tricuspid regurgitation (Supplemental Digital Content, Video 18, http://links.lww.com/AA/B628).

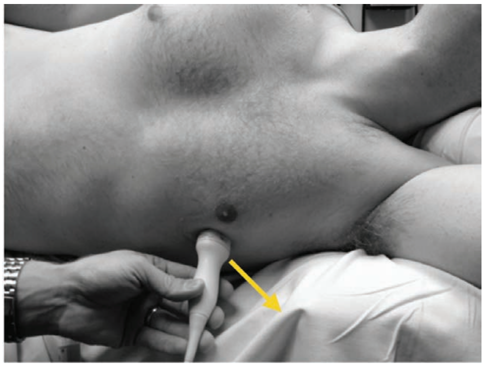

Figure 8. Probe position for the apical 4 chamber. The patient is in the left lateral decubitus position with their left arm extended. The probe is located just inferior and lateral to the left nipple, with the indicator pointed toward 5 o'clock (as viewed from above.) The indicator location and direction is shown by the yellow arrow.

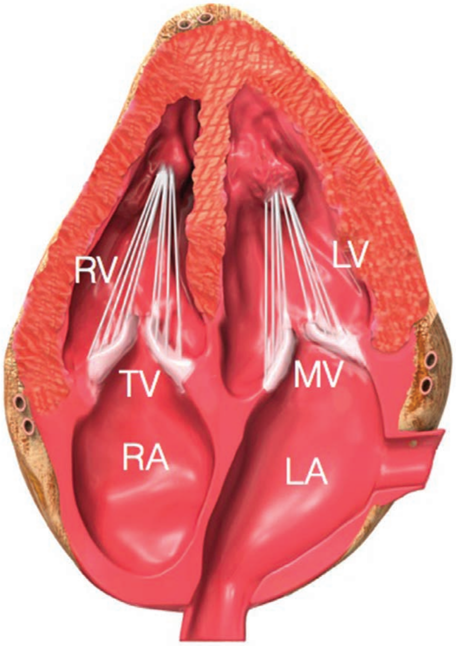

Figure 9. Anatomy of the apical 4 chamber. The apex of the LV should be under the probe, and the right and left atria and ventricles should be seen as well as the mitral and tricuspid valves. LA indicates left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

SUBCOSTAL WINDOW

Patient Positioning. Subcostal images are obtained with the patient in the supine position. In patients who are awake, the tone of the abdominal muscles can occasionally make imaging difficult. In these cases, the patient should place a pillow behind his/her knees or rest his/her feet on the bed.

Subcostal 4-Chamber (SC4) (Supplemental Digital Content, Video 19, http://links.lww.com/AA/B629)

Probe Position and Manipulation. The subcostal window is usually found 1 to 2 cm below the xiphoid process or slightly to the right of midline. There is a tendency for the probe to drift toward the patients left because this is where the heart is known to be, but to make the best subcostal images the liver needs to be used as the window rather than the stomach or spleen. To create the SC4 image, the probe is placed on the abdomen nearly horizontally with the indicator pointing directly to the patient's left (Figure 10). The technique of creating the subcostal window

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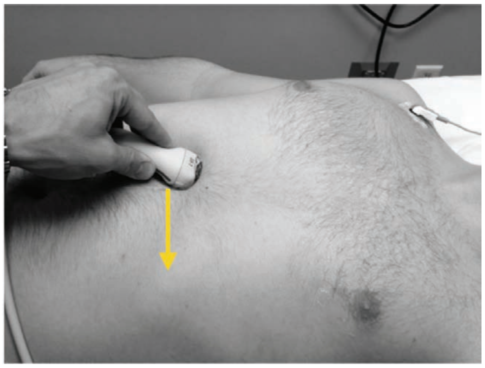

Figure 10. Probe position for the subcostal 4 chamber. The patient is supine with a pillow under his/her knees to relax the abdominal muscles. The probe is 1 to 2 cm below the xiphoid process with the indicator pointing directly toward the patient's left (toward the sonographer.) The indicator location and direction is shown by the yellow arrow.

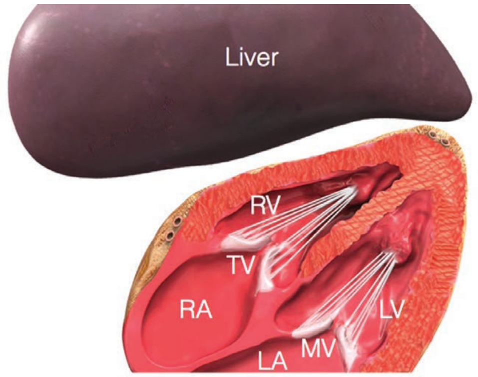

Figure 11. Anatomy of the subcostal 4 chamber. The liver is at the top of the screen. The right and left atria and ventricles can be visualized, along with the mitral and tricuspid valves. It should be noted that this is not the same cross-section as the apical 4 chamber. LA indicates left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

for this image is reminiscent of placing a subclavian central line. The probe is pushed down into the abdomen and forward to create a window that looks toward the heart (located directly under the ribs) rather than a window that looks down into the abdomen. Slight changes in angulation and rotation are then used to create an appropriate SC4.

Breath Control. The subcostal 4 chamber can be improved in some cases by having the patient take a partial or full breath in and hold it. As the diaphragm falls, the probe comes closer to the heart.

Anatomy. Although the view is called the subcostal 4 chamber, and it may indeed show all 4 chambers of the heart, the cross section is not identical to that obtained from the apical window (Figure 11). This view transects a more inferior portion of the right ventricle, and although it may show the inferoseptal and anterolateral walls of the LV, this is less predictable. The benefit of this view is that it shows the free wall of the right ventricle very well. It is a view that complements the information obtained from the other windows. For some patients, particularly those with tubes and drains or those with severe chronic obstructive pulmonary disease, the subcostal window may be the only one that provides adequate imaging, and a detailed 2D assessment of the cardiac structures can often be obtained from this window alone.

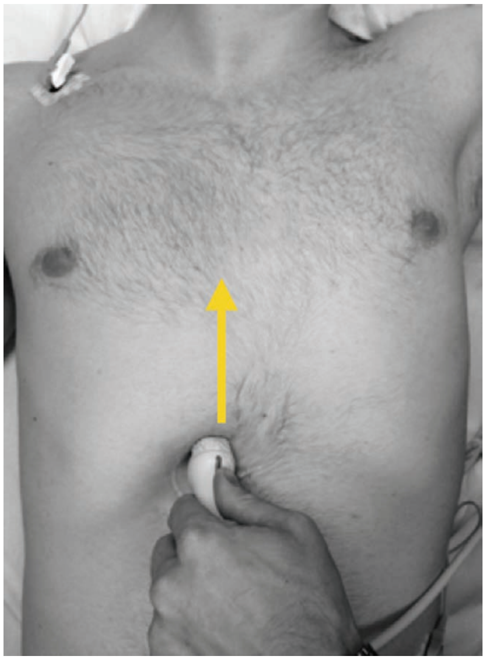

Figure 12. Probe position for the subcostal IVC image. The probe is 1–2 cm below the xiphoid process with the indicator pointing toward the patient's head. The indicator location and direction is shown by the yellow arrow. IVC indicates inferior vena cava.

Assessment.

1. Right ventricle: The SC4 is an excellent view to assess global RV systolic function as described earlier. Although an RV that appears larger than the LV in this view likely represent RV dilation, it is possible for this image to underestimate the size of the right ventricle (Supplemental Digital Content, Video 20, http://links.lww.com/AA/B630). That means an RV that appears normal in size from the SC4 could be falsely reassuring.
2. Pericardial effusion: This is an excellent view to identify the presence of a pericardial effusion. An effusion will appear as an echolucent (dark) space around the right heart (Supplemental Digital Content, Video 21, http://links.lww.com/AA/B631). Findings of tamponade physiology may include right atrial inversion

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during ventricular systole, right ventricular compression during diastole, and inferior vena cava (IVC) dilation (see next section.) As with other complex clinical scenarios, findings of effusion and tamponade should be evaluated within the clinical context.

Subcostal IVC Long Axis (Supplemental Digital Content, Video 22, http://links.lww.com/AA/B632)

Probe Position and Manipulation. Starting from the SC4, the probe should be tilted to center the right atrium in the screen. Then a slow counterclockwise rotation of the probe by 60 to 90° should show the IVC entering the right atrium. (Figure 12).

Anatomy. At the top of the image is the liver, with the IVC appearing near-horizontal on the screen as it enters the right atrium. It is important to distinguish the IVC from the abdominal aorta in this view. The aorta is thick-walled and will often have obviously systolic pulsatility. The IVC is thin-walled, can be seen to enter the right atrium, and has hepatic veins draining into it. The left hepatic vein can often be identified entering the IVC at the 12-o'clock position near the right atrium (Figure 13).

Assessment. The utility of this view is to evaluate the relative size and behavior of the IVC to aid in the assessment of volume status and fluid responsiveness.[3] An IVC that appears large with minimal change in diameter with ventilation (spontaneous or controlled) suggests relatively greater right atrial pressures and a lower likelihood of volume responsiveness (Supplemental Digital Content, Video 23, http://links.lww.com/AA/B633). A very small appearing IVC suggests a patient that is likely volume responsive (Supplemental Digital Content, Video 24, http://links.lww.com/AA/B634). Because assessment of volume status is one of the more complex aspects of cardiac ultrasound, it is important to view this information in the broader clinical context and not to use IVC assessment as the sole determinant.

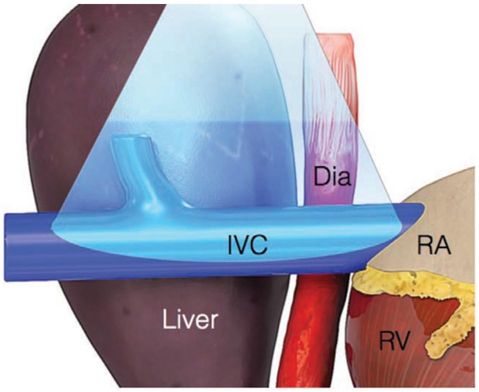

Figure 13. Anatomy of the subcostal IVC. At the top of the image is the liver. The IVC can be seen entering the right atrium. The left hepatic vein is seen entering the IVC near the right atrium. Dia indicates diaphragm; IVC, inferior vena cava; RA, right atrium; RV, right ventricle.

IMAGE STORAGE AND REPORTING

The days when perioperative echocardiographers could make images, act on the findings, store no images, and report no findings are gone. At this early stage of the adoption of point-of-care ultrasound, the authors recommend applying the current standards for medical imaging to all forms of point-of-care ultrasound and to FoCUS in particular. That means images should always be archived, either on an imaging server or on disks, for review and quality assurance. Every currently available ultrasound device has some mechanism for image storage. Likewise, there should be some mechanism for reporting the findings of each FoCUS examination. Paper forms can be used (an example used by the authors is included in the Supplemental Digital Content, http://links.lww.com/AA/B687), electronic forms can be created, or information can be reported in the anesthetic record.

CONCLUSIONS

The field of perioperative echocardiography is broad, complex, and takes years to master. FoCUS, on the other hand, can provide significant value in the care of complex patients with substantially less time and experience. This article provides a brief introduction to the techniques of FoCUS and the reader with further interest is strongly encouraged to seek further instruction.

DISCLOSURES

Name: Josh M. Zimmerman, MD, FASE.
Contribution: This author was the primary author, and was responsible for writing and editing this article.
Name: Bradley J. Coker, MD.
Contribution: This author helped with the writing and editing of the article.
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Supplemental Online Material 3

EXPERT CONSENSUS STATEMENT

Focused Cardiac Ultrasound: Recommendations from the American Society of Echocardiography

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1. WHY IS A GUIDELINE NEEDED?

The value of ultrasound as a diagnostic cardiac modality is in many respects unparalleled. It is more portable and less expensive compared with other imaging modalities (computed tomography, magnetic resonance imaging, nuclear perfusion imaging). Unlike methods that expose patients to radiation, there are no known adverse effects of ultrasound used at diagnostic imaging intensities, which allows safe, serial evaluation of patients. Echocardiography permits rapid assessment of cardiac size, structure, function, and hemodynamics. Ultrasound images are evaluated in real time, which allows rapid diagnostic interpretation in a wide variety of settings, such as the outpatient clinic, inpatient ward, critical care unit, emergency department, operating room, remote clinic, and cardiac catheterization laboratory. Cardiac ultrasound is used across the entire spectrum of patient care from in utero to the frail elderly patient. Echocardiography is sensitive and specific for a broad range of clinical disorders, which allows evaluation of a wide variety of parameters with well-documented prognostic utility. In an effort to increase the value of echocardiography even further, platforms have been developed that incorporated advanced imaging capabilities (three-dimensional [3D], strain imaging) and complex algorithms for quantitative analysis.

Equally important to the technical performance of this modality is the training of the clinicians who use it. Even before images are

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Abbreviations

ADHF = Acutely decompensated heart failure

ASE = American Society of Echocardiography

CPT = Center for Medicare Service's Current Procedural Terminology

DICOM = Digital Imaging and Communications in Medicine

eFCU = Expert FCU

EKG = Electrocardiographic

FCU = Focused cardiac ultrasound

ICU = Intensive care unit

IVC = Inferior vena cava

LA = Left atrium

LV = Left ventricle

LVH = Left ventricle hypertrophy

LVSD = LV systolic dysfunction

RA = Right atrium

RV = Right ventricle

TTE = Transthoracic echocardiography

2D = Two-dimensional

3D = Three-dimensional

acquired, physicians who perform echocardiography need to be knowledgeable about the appropriate uses of the technique.[1] Accurate clinical use of cardiac ultrasound is completely dependent on users who are trained in image acquisition, analysis, and interpretation. Given the extensive expertise required for accurate use, guidelines have been established for the knowledge base, practical experience, and continued maintenance of competency for echocardiographic image acquisition.[2-4] Image analysis, interpretation, and reporting require extensive training. Recommendations for these also exist.[2,4,5] In addition, there are comprehensive guidelines that incorporate extensive recommendations for echocardiographic use in clinical practice.[6-12] The expertise required to use advanced platforms and the extensive training required to appropriately analyze and interpret transthoracic images have traditionally only been fulfilled by specialists in cardiovascular medicine.

Two major developments have changed the practice of cardiac ultrasound:

- Development of small ultrasound platforms. These devices have significantly fewer features and capabilities, which make them easier to operate. Despite their small size, they have proven diagnostic utility when used by physicians with comprehensive echocardiographic training.[13-20] Simplified operation and substantially smaller size and cost have opened their potential use to nontraditional cardiac ultrasound users. However, the easier operation of small devices does not obviate the need for training to acquire and interpret cardiac images.
- Physicians from diverse specialties have become interested in having access to the diagnostic value of cardiac ultrasound in clinical settings relevant to their scope of practice. This has led to the concept of focused use of cardiac ultrasound. The hypothesis is that nontraditional users, who have less training in cardiac image acquisition and interpretation compared with those trained in echocardiography, can learn to acquire and interpret cardiac ultrasound images as an adjunct to their physical examination assessment.

It is important to maintain excellence in the practice of echocardiography, a discipline that requires significant training and knowledge of guidelines for acquisition, analysis, and interpretation, while enabling ultrasound to be used as a tool by nonechocardiographers to augment their clinical assessments traditionally based on physical examination alone. It is recognized that there is a broad continuum of imaging and interpretive expertise among physicians with cardiac ultrasound training. Some users may understand more advanced imaging acquisition, analysis, and interpretation. However, as in most areas of medicine, specific thresholds of expertise need to be defined. This is critical to providing excellent patient care by holding physicians accountable to practice within their scope of expertise as well as setting expectations for the practitioner, referring physician, and patient. The current document distinguishes the emerging field of focused cardiac ultrasound (FCU) as a bedside adjunct to the physical examination and echocardiography. Defining the distinctions between these techniques will allow practitioners to realize the utility of FCU and yet maintain the value of echocardiography. This guideline will not address ultrasound imaging outside of the cardiovascular system or nontransthoracic ultrasound modalities (ie, transesophageal echocardiography). This guideline is specific to cardiac imaging in the adult.

2. DEFINITIONS

a. What is FCU?

FCU is a focused examination of the cardiovascular system performed by a physician by using ultrasound as an adjunct to the physical examination to recognize specific ultrasonic signs that represent a narrow list of potential diagnoses in specific clinical settings.

b. Terminology

There are a variety of terms that have been used to describe a focused ultrasound of the heart. The importance of defining the nomenclature is the recognition that these procedures are distinct from the practice of echocardiography, as outlined in section 3. The American Society of Echocardiography (ASE) recommends the use of the term "focused cardiac ultrasound," but recognizes that other terms are in use (Table 1). The literature also contains hybrid terms that should be avoided because the expectations of the examination, equipment used, expertise in image acquisition, and proficiency in data analysis and interpretation are unclear if these terms are used. Such terms include "focused echocardiography," "hand-held echocardiography," "hand-carried echocardiography," "point of care echocardiography," and "directed echocardiography." The appropriate terminology for echocardiography has previously been established and includes "complete" or "comprehensive" echocardiography and "limited" echocardiography.

3. DIFFERENTIATION OF FCU AND "LIMITED TRANSTHORACIC ECHOCARDIOGRAPHY (TTE)"

The technical requirements for equipment, expertise for image acquisition, and the knowledge base for image analysis and interpretation have been well defined for echocardiography. This permits the appropriate and safe use of echocardiography in an unlimited number of clinical scenarios and permits its users to have a very broad scope of practice. Because of equipment capability, image acquisition training, image interpretation training, and image interpretation knowledge base, the practitioner of FCU will have a scope of practice that is restricted to the equipment and skill set that he or she possesses. The scope of practice may be a specific patient population or a clinical setting. The specific clinical question to be addressed and the cardiac abnormalities that can be ruled in or out with the focused examination will be narrow. The difference between the limited

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Table 1 Terms in use that may refer to FCU

Hand-held cardiac ultrasound
Point-of-care cardiac ultrasound
Ultrasound stethoscope
Hand-carried cardiac ultrasound
Bedside cardiac ultrasound
Quick look cardiac ultrasound

Table 2 Differences between limited echocardiography and FCU

Limited echocardiography
Definitive examination that requires knowledge and expertise described below
Knowledge that specific additional images would be useful
Expertise to acquire additional images from all acoustic windows
Knowledge that a specific additional ultrasound technique would be useful
Expertise to acquire additional images with all cardiac ultrasound imaging modalities
Knowledge to identify all expected normal structures and/or artifacts from all views
Knowledge to identify pathologic findings on structure of clinical interest
Knowledge to look for and identify lesions associated with other findings, whether in the same view of other parts of the study
Knowledge to identify incidental findings within images acquired
Knowledge of quantitative techniques
Expertise to apply quantitative techniques
Expertise to answer any referral question with appropriate negative and positive pertinent findings
FCU
Identify the presence or absence of one or several specific findings by using a defined, preestablished image acquisition protocol

echocardiogram and FCU rests in the expectations of the examination, the equipment used, the expertise in image acquisition, and proficiency in data analysis and interpretation. “Limited” refers to a reduced number of images, whereas “focused” refers to a narrowed, specific question and scope of expertise (Tables 2 and 3).

a. Examination Expectations

With FCU, subjective interpretation of one or a few prechosen targets of interest is emphasized, with the intent that subsequent referral for an echocardiographic study will delineate and measure all findings, including incidental or associated findings, which may go unrecognized by FCU. Abnormalities when using FCU are typically classified as present or absent by using a predefined specific imaging protocol. The practitioner is “focused” on making a specific diagnosis or identifying a potentially significant valvular, hemodynamic, or structural abnormality. This approach allows rapid detection of a small number of evidence-based targets at the bedside that could provide clues to the patient’s cardiac status and requires less training and expertise than that considered adequate to perform echocardiography. The results of an FCU examination can be used in conjunction with other bedside measures, such as the physical examination, in formulating an initial diagnostic impression and guiding appropriate early triage and management.

Although a FCU evaluation may facilitate initial management, all patients with abnormal findings not previously documented on echocardiography should be referred for a comprehensive echocardiographic examination. A physician with only FCU expertise does not have the image acquisition or interpretation expertise to completely evaluate a symptomatic cardiac patient. Comprehensive echocardiography allows additional characterization of an abnormality from supplementary views, complete assessment of the hemodynamics associated with a lesion and further evaluation of a finding with additional ultrasound tools (Doppler, 3D, etc). When FCU evaluation fails to detect any prespecified abnormalities in a patient with symptoms or signs of cardiovascular disease, referral for comprehensive echocardiography is probably warranted. For example, in a patient with dyspnea, although FCU may allow rapid and accurate exclusion of a large pericardial effusion or significant left ventricle (LV) systolic dysfunction, numerous other cardiac pathologies missed by FCU, but detectable by comprehensive echocardiography, remain to be investigated as alternative causes of the patient’s breathlessness.

The implications of the FCU examination go beyond its terminology in regard to the perception of the act by the patients, their families, health care professionals, and the legal profession. Patients who undergo or witness an FCU examination should be informed that this particular use of ultrasound is a new method that is meant to enhance bedside examination by providing “early” or “preliminary” information that is used to formulate the physician’s initial impression. Importantly, it is not equivalent to a diagnostic echocardiographic study. The operator is incorporating his or her recognition and knowledge of specific findings within the scope of his or her clinical practice in the care of the patient. Patients and their families should be told that significant abnormal findings will be confirmed with a complete diagnostic echocardiogram. Patients should understand that an echocardiogram will be performed as soon as practical if their symptoms or signs warrant one. Likewise, when patients undergo echocardiography after an FCU examination, they should understand that this is not a duplicate or repeated examination but a comprehensive evaluation of their condition by an expert in cardiac imaging.

With echocardiography, the whole sum of knowledge is applied “upfront,” with measurements of normal structures and function, documentation of findings other than those that may have prompted the referral, and a thorough search to answer the referral question. The ASE has provided detailed recommendations for the performance, interpretation, documentation, and image storage that apply to comprehensive and limited echocardiographic examinations.[2] These standards were developed to contribute to patient and provider satisfaction, and to improve patient outcomes.

The “limited” descriptor of a limited echocardiogram simply refers to the fact that, compared with a comprehensive examination, the number of views obtained and the number of images that are acquired are fewer. Every other aspect of limited echocardiography is the same as for comprehensive echocardiography. The practitioner will completely interpret all available data from all images, albeit in a limited echocardiogram from a more “limited” number of images. The clinical decision to perform a limited echocardiogram, as opposed to a comprehensive examination, requires expertise in echocardiography and specific knowledge of the appropriate indications. When performing a limited echocardiogram, the imager must have the knowledge of all views necessary to characterize or exclude the referral diagnosis. In addition, a clinician performing a limited echocardiogram must be cognizant of the potential to miss findings not in the field of view that (1) could offer an alternative explanation for the patient’s referral or (2) are incidental but clinically significant.

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Table 3 Differences between limited echocardiography and FCU

	Limited echocardiogram	FCU
Patients	Any adult patient	Defined scope of practice
Location of imaging	Any location	Defined scope of practice
Image protocol	Skill to perform any view, but only selected views may be required	Limited number of views
Equipment	Full function (M-mode, 2D, color Doppler, spectral Doppler, TDI, contrast), EKG gated	2D minimum
Transducers	Multiple	Single
Measurements	Advanced quantification	None or linear measurement
Acquisition	Sonographer or level II/III echocardiographer	Physician with FCU training
Interpretation	Echocardiographer; all pathology and normal structures within imaging view	Physician with FCU training defined, limited scope
Image storage	DICOM format, archived for easy retrieval and review	Only for select indications (see text)
Documentation	Formal report meeting ICAEL standards	Documentation as brief report or as part of PE depending on indication
Billing	93308	None

TDI, Tissue Doppler imaging; *ICAEL*, Intersocietal Commission for the Accreditation of Echocardiography Laboratories; *PE*, physical examination.

A limited echocardiogram is more often used as a follow-up examination, after a prior comprehensive echocardiogram has delineated all findings. When performing limited echocardiography, report generation and comparison with prior studies must follow standard requirements of echocardiography.

b.Equipment

Ultrasound machines have evolved from large, poorly moveable devices to hand-carried ultrasound instruments and now pocket-sized devices. It is not the size or weight characteristics that define an echocardiographic machine. The use of FCU in this document generally applies to a nonechocardiographer imager who is using a basic ultrasound device. However, nonechocardiographer users who acquire images with a high-end platform or users trained in echocardiography who use pocket ultrasound devices are also performing FCU (Table 4).

The equipment used for limited echocardiography should be capable of performing two-dimensional (2D) echocardiography, M-mode, color-flow imaging, and spectral and tissue Doppler ultrasound. Although all of these modalities may not be used in every case, their availability is critical in preserving the expectation that a patient referred for echocardiography (whether limited or complete) will receive the examination needed to delineate all abnormalities. Platforms for FCU are intended to answer a specific clinical question within the technologic limitations of a small device and thus do not require all these modalities.

Echocardiographic examinations (comprehensive and limited) require that a broad selection of transducers be available for use, whereas FCU does not. In the process of miniaturization, many of the fundamental capabilities of an echocardiogram have been omitted, including advanced signal processing and electrocardiographic (EKG) gating. The small screen size and reduced image resolution on devices used in FCU may limit recognition of diagnostic findings. The platform of a typical FCU device is incompatible with the performance of detailed or gated measurements that are the minimum professional standard for echocardiography. Echocardiographic platforms must store images in a method compatible with DICOM (Digital Imaging and Communications in Medicine) standards. Platforms that do not export in the DICOM format should not be used to perform echocardiography (limited or comprehensive).

Table 4 Types of cardiac ultrasound examinations by level of training and nature of equipment

	Training level	
Equipment capabilities	Nonechocardiographer	Echocardiographer
Basic	FCU	eFCU
Comprehensive	FCU	Echocardiography

c.Image Acquisition

Differentiating the image acquisition aspects of FCU and "Limited TTE" is best made by noting the requirements for image acquisition for limited echocardiography. Guidelines for specific training and credentialing of sonographers and physicians to acquire images in echocardiography have been published.[2,4,21] Specific imaging components for completion of a comprehensive examination are specified. Practitioners who perform limited echocardiography need familiarity with all the windows and views of a comprehensive examination, because different clinical situations may require a particular subset of a comprehensive examination. Limited echocardiographic examinations may require any or all of the modalities used in a comprehensive examination. Practitioners who perform limited echocardiography need to be proficient in 2D, pulsed-wave and continuous-wave Doppler, color-Doppler, tissue Doppler, and M-mode echocardiography. The limited echocardiographic acquisition skill set must include familiarity with all transducers used in comprehensive echocardiography, because the clinical question, which may be answered with a limited echocardiogram examination, may require any of a number of transducers. Image quality of a limited echocardiographic examination is expected to be equal to comprehensive echocardiography to provide comparable data for side-by-side comparisons during assessment of temporal changes in patient status.

d.Image Interpretation

In the practice of limited echocardiography, the user is responsible for interpretation and delineation of primary, associated, and "incidental" findings that are apparent or became apparent while obtaining the

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views. Similar to the radiographic standard of chest X-ray interpretation in which the radiologist is accountable for the diagnosis of a solitary pulmonary nodule even when the primary cardiac finding of the radiograph is cardiomegaly, a limited echocardiogram that "excludes" a pericardial effusion is still accountable for a diagnosis of any evident wall-motion abnormality, valvular disease, or significant finding clearly present in the specific views recorded. Moreover, the interpretation must include assessment of key structures and cardiac function, including performance of measurements when feasible. Finally, there must be a report that includes key elements of cardiac structure and function, findings, and interpretation.

In these circumstances, an echocardiogram, comprehensive or limited, provides the maximum ultrasonic diagnostic capabilities and expert interpretation and upholds the perceived standards and justified costs of the echocardiogram held by the referring physician, patient, and payers. FCU does not require quantitation or provide equivalent diagnostic capability, and it is not the expectation of the user to delineate and quantify all findings viewed.

e.Billing

In the United States, the Center for Medicare Service's Current Procedural Terminology (CPT) codes provides a system in which a participating health care provider can bill for the particular services rendered. The calculated reimbursement for a procedure is determined on a "relative value" scale that takes into account practice expense, physician work, malpractice costs, and the relative value of the procedure adjusted to regional factors where the service was rendered, the so-called resource-based relative value scale. In calculating the physician work component for limited echocardiography, the following factors are considered: physician time, technical skill, physical effort, mental effort, judgment, and stress due to potential risk to the patient. The submission of limited echocardiographic CPT (93308) for FCU would be inappropriate because the components used in the resource-based relative value scale cost estimates for FCU and limited echocardiography are different.

Practice expenses are different primarily due to the substantial differences in machine, room, documentation, image storage, and personnel costs. Liability is different because the echocardiographer is responsible for interpretation and delineation of primary, associated, and "incidental" findings that are apparent or became apparent while obtaining the images. FCU users are responsible for recognizing a focused list of potential diagnoses in specific clinical settings within their scope of practice. Finally, the physician work component, which includes time, technical skill, and mental effort, is entirely different between FCU and limited echocardiography. FCU is not a procedure described under current echocardiographic CPT codes. Use of the limited echocardiography code for FCU is not appropriate because the resource-based determination for reimbursement was made by assuming the standards established for echocardiography.

4. CONSIDERATIONS FOR SUCCESSFUL USE OF FCU AS AN ADJUNCT TO PHYSICAL EXAMINATION

a. Personnel

Rapid evaluation to expedite patient triage and early management is an important role of specialists in emergency medicine. Assessment of critically ill patients after hours or at the bedside after a sudden change in clinical status is a role of critical care physicians. Internists, surgeons, and hospitalists perform serial evaluations of hospitalized adult patients daily. These are all situations when a sonographer or level II/III trained physician in echocardiography are potentially not immediately available or cannot be present for daily image acquisition. All these physicians could potentially use FCU to augment their cardiac physical examination assessment. As long as the training requirements are met and maintenance of competency and quality assurance are documented, many adult medical and surgical specialties could potentially use FCU. It is essential that physicians who use FCU have realistic expectations of their abilities to image and interpret as well as knowledge of the limitations of FCU devices. Inappropriate interpretation or application of FCU beyond a defined scope of practice may have adverse consequences for patient care.

Sonographers and physicians with level II or III training in echocardiography can acquire images without additional training, and physicians with level II or III training in echocardiography can interpret FCU images. Although these practitioners have the required expertise for image acquisition and interpretation, if using a device typically used for FCU, then they would not be performing echocardiography. For the purposes of distinction, this document refers to this as expert FCU (eFCU). Use of FCU by medical students should be for educational or training purposes only, under the direct supervision of an echocardiographer or a trained FCU physician.[22] Likewise, use by nurses or other allied health care professionals who are not registered cardiac sonographers should be for research purposes only and not for clinical use.[23,24]

b. Equipment

Ultrasound platforms for cardiac imaging can be broadly characterized into 4 groups:

(1) Full functionality platforms. These devices have the complete range of echocardiographic image acquisition capabilities (M-mode, 2D, color-Doppler, spectral Doppler, tissue Doppler), have advanced quantification and analysis packages, permit acquisition, and processing of stress images, have advanced image processing for contrast enhancement, and have a wide array of specialized transducers for advanced functions such as transesophageal and 3D echocardiography.
(2) Small ultrasound platforms. These machines typically support the standard echocardiographic modalities (M-mode, 2D, color Doppler, spectral Doppler, transesophageal echocardiography, and stress) but are smaller and may lack advanced imaging options.
(3) Hand-carried platforms. These machines, which generally weigh 6-12 pounds, are readily carried by a user to the bedside or may be cart based. These typically have standard cardiac ultrasound capabilities and may have fundamental quantification packages.
(4) Pocket platforms. These devices are compact and can be placed in a lab coat pocket. Pocket ultrasound instruments include basic ultrasound functionality such as 2D imaging and may or may not have color Doppler.

Although an FCU examination can be performed with a full functionality ultrasound platform, the size, expense, and complexity of these instruments are disparate with the clinical settings in which FCU is useful as well as the abilities of an FCU provider. Small ultrasound platforms can also be used by a nonechocardiographer to perform an FCU assessment. However, the cost of these devices makes their use solely as an adjunct to the physical examination impractical. In some hospital intensive care units (ICU) or emergency department settings, these machines are used for other diagnostic (noncardiac) procedures and, therefore, available for FCU use. Use of these small platforms capable of performing echocardiography by a practitioner without echocardiographic training and imaging and/or interpretation expertise should be considered FCU, not limited echocardiography. In practice, these devices are typically used by practitioners with

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comprehensive echocardiographic acquisition and interpretation skills in settings in which their smaller size is an advantage.

The devices ideally suited for FCU extension of physical examination use a simpler technology compared with full-functionality echocardiographic platforms. Most reports that evaluated FCU by nonechocardiographer users have been with hand-carried platforms. Although pocket-sized instruments have shown clinical promise, the published literature consists primarily of their use by experienced imagers or cardiology fellows.[13-20,25-32] It is possible that the reduced imaging abilities and smaller screen will make it more difficult for nonechocardiographer practitioners to use pocket devices accurately.

FCU equipment must consist of a transducer with a frequency appropriate for adult patients. Minimum display requirements include the ability to label the images with at least 2 patient identifiers, date and time of examination. Electronic calipers are not required, but there should be markers that indicate scale or image depth. Measurement packages are not standard, because much of the clinical functionality of FCU is for rapid qualitative assessment. Minimum functionality consists of 2D grayscale imaging and controls for depth and gain adjustment. Studies or images used to evaluate a symptomatic patient to direct management because formal echocardiography is not available should be stored in a retrievable location. Ideally, stored images should be in the DICOM format and be exportable to the digital archive where the patient's echocardiographic images are stored.

Additional functionality is available on hand-carried and pocket devices. These capabilities (color-Doppler, spectral Doppler and tissue Doppler) require more training to appropriately use and interpret, which would extend the duration of FCU instruction. In addition, these capabilities are typically not needed for the scope of FCU practices. Demonstrating that the extra training and device costs for color-Doppler FCU adds clinical value would require that (1) FCU augmented physical examination could detect clinically important valvular lesions not already apparent by physical examination, and (2) the early bedside identification of the valvular lesion makes a clinically important difference over having it detected at the time of a standard TTE. Supplementary functionality only seeks to increase the costs of the devices, potentially reducing their cost-effectiveness. There also is concern that users may attempt to implement features or functionality without the proper training, which potentially results in erroneous clinical conclusions and adverse patient outcomes. Although an echocardiographer or qualified sonographer would have the training to acquire images by using these additional functionalities of a hand-carried or pocket ultrasound, the clinical scenarios when this would be preferred over a standard platform with better quality imaging and more capabilities are infrequent and discussed in a later section of the article (eFCU).

c. Potential Limitations of FCU

Using FCU as an adjunct to physical examination is facilitated by using smaller ultrasound devices (hand carried or pocket). However, these devices may not have the capabilities to image all findings. A system that weighs less than 10 pounds with an estimated cost between $8,000-$30,000 should not be expected to produce the image quality of a 200 pounds, $200,000 system. The transducer technology is not the same, and the complex image enhancement and artifact reduction abilities cannot be reproduced on an FCU machine. In addition, the images are visualized on a screen with significantly lower resolution and size compared with those available with state-of-the-art echocardiography. Commonly performed acquisition modifications, such as the ability to zoom, alter the ultrasound beam focus, narrow sector width, adjust dynamic range, use harmonic imaging, use settings optimized for contrast, change grayscale maps, or optimize transducer frequency, may be lacking. These restrictions make identification of subtle abnormalities inappropriate for FCU scope of practice. Despite these limitations, small devices with specifications that are inadequate for performing echocardiography can generate clinically useful images.

Instruments used for FCU have been miniaturized to improve functionality at the bedside. The compromise of smaller devices is loss of features, including spectral Doppler, tissue Doppler, and 3D. This concession is certainly worthwhile because it allows the devices to be smaller and less expensive. Lack of spectral Doppler makes FCU inappropriate for the assessment of pericardial constriction, pulmonary hypertension, and diastolic dysfunction. Quantitation of regurgitant or stenotic valvular lesion severity is also not appropriate with FCU. However, the morphology of stenotic valves and secondary findings, such as chamber enlargement and hypertrophy, to suggest pressure or volume overload or left ventricle (LV)-right ventricle (RV) interaction may still be detected by the astute user. Color Doppler is available on most systems and has been used to qualitatively assess for potentially severe regurgitant lesions of the aortic and mitral valve.

To distinguish the limitations of the smaller devices from the skill of the user, the writing group reviewed studies that included at least 50 patients in which a small platform was compared with traditional echocardiography, with all images acquired and interpreted by experts to determine which pathologies FCU devices are capable of detecting despite their reduced functionality. Articles that use cardiology fellows as imagers were not included. Cardiac abnormalities that have been accurately detected included the following:

- LV enlargement[18,19,29,33-35]
- LV hypertrophy[19,29,30,35-39]
- LV systolic function[16,18-20,28,30-32,34-37,39-45]
- LA enlargement[28-30,34-36,42,43,45]
- RV enlargement[30,35,42]
- RV systolic function[28,31,32,34,39,42]
- Pericardial effusion[20,28,30-32,35,37,39-42]
- Inferior vena cava (IVC) size[30,44]

There are a variety of both standard and nonstandard echocardiographic windows used to assess cardiac structures. From each window, multiple views and sweeps of the heart are typically acquired. There is no question that certain windows and/or views are easier to learn than others. The parasternal and subcostal views, for example, are typically easier to master. The landmarks for these windows are characteristically more reliable. Imaging from the parasternal window is easier to hold stable and consistently provides more interpretable images than the apical views. Parasternal views are less dependent on patient positioning and less subject to interference from patient body habitus. The parasternal window is preferred for the assessment of LV systolic function by less experienced users.[46] Proficiency in acquiring adequate parasternal views by novices under direct proctoring is similar to acquiring an apical 4-chamber view but much easier than the apical 2-chamber view.[47]

Other views, such as the apical planes, are more difficult to optimize and require expertise to correctly adjust patient position and breathing cycle to acquire. In addition, apical views require a more powerful transducer with higher penetration, which may not be available with hand-carried or pocket-sized platforms.

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Optimization of cardiac views is critical to obtaining a correct diagnosis. Nonexpert imagers obtain adequate images from the parasternal view nearly twice as often as from the apical views with an FCU device.[26] It is also clear that off-axis imaging and foreshortening from the apical views can lead to incorrect conclusions and erroneous clinical management. Nonexpert imagers must be aware of the pitfalls and limitations of apical imaging before imaging is attempted. Because of these factors, the parasternal and subcostal views are preferred for FCU imaging. Diagnoses that depend on nontraditional windows (right parasternal, suprasternal) should not be made or excluded with FCU.

Complex or unusual cardiac disorders should not be expected to be diagnosed by a physician solely trained in FCU. In addition, some pathologies are subtle and are difficult to recognize (LV wall motion). Other abnormalities require assimilation of data from multiple views to correctly define (RV systolic function and size). Certain findings on a cardiac ultrasound image may only make sense considered in the context of a broader picture, which requires extensive training in cardiovascular disease, such as in patients with congenital heart disease or other uncommon disorders. Because these are beyond the experience of FCU training and experience, the following pathologies are unlikely to be accurately detected by FCU examination: aortic dissection, hypertrophic cardiomyopathy, LV regional wall-motion abnormalities, LV aneurysm, cardiac masses, RV hypertrophy, LV thrombus, and valvular vegetations.

Although small ultrasound devices have been used to demonstrate a broad range of pathology in the hands of a sonographer or echocardiographer (cardiovascular specialist with level II or III echocardiographic training), this document seeks to review the cardiac abnormalities that nonechocardiographer users have successfully identified. It is important to realize that most FCU studies are designed to evaluate the ability to image and interpret significant abnormalities, such as moderate or severe deviations from normal. Most abnormalities are defined by FCU users as present or absent. The broader experience to characterize pathologies into severities of abnormality should not be expected with FCU.

The available published studies are methodologically inconsistent in regard to the duration and nature of training, provider background, patient population, devices used, and the clinical settings for the FCU examination. The writing group reviewed studies, including at least 50 patients in whom a small platform was compared with traditional echocardiography or another criterion standard, with all images acquired and interpreted by physicians with no or minimal prior training in cardiac ultrasound, to determine which pathologies a physician performing FCU can discern. The most commonly studied pathology that was adequately detected by using FCU was LV systolic dysfunction, in which sensitivities of 73%-100% and specificities of 64%-96% have been demonstrated. Other abnormalities with significantly less validation include LV enlargement,[48,49] LV hypertrophy,[30,50] LA enlargement,[48,51,52] RV enlargement,[30] pericardial effusion,[30,48,51] and IVC size.[30,53-57]

Most importantly, although the ability to detect abnormalities at the bedside by FCU users is lower than having a comprehensive TTE, it is clearly better than traditional bedside assessment. FCU use allows detection of cardiac pathology more accurately than physical examination, which supports its use as an adjunct to physical examination, not as a replacement for echocardiography. When used by physicians without formal echocardiographic training, FCU is superior to physical examination for the detection of cardiac abnormalities, including LV enlargement, LV systolic dysfunction, LA enlargement, LV hypertrophy, pericardial effusion, and RA pressure elevation.[30,39,49,53,58-61]

5. FCU SCOPE OF PRACTICE

As with any clinical tool, inappropriate application of FCU beyond a defined scope of practice may have adverse consequences on patient diagnoses, triage, and management. One paradigm is to use FCU routinely as an adjunct to the physical examination with every patient encounter. However, the impact of widespread use of FCU in all patient encounters that involve a physical examination has not been tested. The implications of following up on abnormalities detected by routine use of FCU at the time of physical examination, many of which would be false positives, needs to be considered. In addition, the potential impact of failure to refer symptomatic patients for complete echocardiographic evaluation, because of a "normal" FCU physical examination, needs to be considered. The infrastructure to educate and train all physicians who perform physical examination in FCU would be a massive undertaking. Although this may represent the future of cardiac examination, the introduction of FCU as an adjunct to physical examination into specific clinical settings to answer a particular clinical question seems more prudent at this time.

It seems that the greatest value of FCU is as an adjunct to the history and physical examination in an attempt to provide more rapid and appropriate patient management in the early phases of his or her presentation. It is impractical to enumerate the specific clinical settings or patient conditions in which FCU-assisted physical examination might prove useful. Rather, general clinical settings are described in which (1) an FCU trained clinician needs to assess a patient at the bedside, (2) FCU would improve the clinician's assessment over the tools that would otherwise be available, such as a stethoscope and one's hands, and (3) echocardiography is not available, not available quickly enough, or impractical. Although additional indications may be described, the focus of this discussion is limited to settings in which clinical value has been documented in the literature. The risk of a false-negative FCU examination that leads to delayed treatment or a false-positive examination that results in unnecessary treatment must be recognized.

In these contexts, it is important to state that individuals performing FCU will be making direct interventions based upon their findings, just as they would based on their physical examination and basic laboratory findings. FCU is not just to detect disease, but clinicians will be able to act upon the findings. However, most studies that evaluate FCU have focused on evaluating image quality and accuracy to detect specific abnormalities in comparison with full-featured platforms and have not addressed the added value of FCU. There are limited data on the use of FCU by nonechocardiographer users to affect medical decision making or alter time to diagnosis and initiate treatment. There is a need to demonstrate in which setting FCU improves outcomes. Because FCU use directly affects patient care, it is imperative that clinicians keep to their scope of practice. Medically unwarranted overuse is a serious concern that justifies the establishment of rigorous standards for training and scope of practice.

a. FCU When Echocardiography is Not Promptly Available

i. The need for clinical evaluation is emergent or urgent and echocardiography is not immediately available

The need for emergent and/or urgent clinical evaluation may occur in patients with hemodynamic instability or chest trauma, and with findings that suggest the possibility of pericardial tamponade. These types of emergent evaluations generally are performed in the emergency department or the ICU. FCU in these settings clearly adds to

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the bedside physical examination and can be performed immediately at the bedside.[62] In patients who are critically ill, FCU has been shown to be helpful to traditional bedside assessment in determining volume status and LV systolic function.[55,56,63-66] In patients who are hemodynamically unstable, FCU diagnoses may impact therapy in terms of the use of volume repletion, vasopressors, and inotropes, as well as diuretics and vasodilators. FCU may also be used to identify findings suggestive of pulmonary embolism (RV enlargement). Although RV enlargement lacks both sensitivity and specificity for pulmonary embolism; if present, this may alter triaging of further diagnostic testing. Findings from FCU are not definitive; the presence of ultrasound signs must be integrated with other bedside information to form an initial diagnostic impression that can then be pursued with alternative imaging or diagnostic modalities.

Patients who have had cardiac arrest may also benefit from FCU. During cardiopulmonary resuscitation, FCU has been used to evaluate for large pericardial effusion suggestive of cardiac tamponade and to evaluate for cardiac standstill when deciding to cease resuscitative efforts. FCU may help guide early post-arrest management by allowing rapid assessment of LV systolic function, pericardial tamponade, signs of pulmonary embolism, and volume status, all findings difficult to confirm by physical examination alone. In patients with chest trauma or findings consistent with pericardial tamponade, FCU can readily be used to identify the presence or absence of pericardial effusion. Comprehensive echocardiography should be performed for confirmation of abnormal findings as well as evaluation of LV regional wall motion, valvular heart disease severity, and loculated pericardial effusions if clinically suspected.

ii. Echocardiography not immediately available and the findings from FCU facilitated physical examination would allow more rapid triage and directed clinical management

In patients with acutely decompensated heart failure (ADHF), FCU can be used to readily distinguish those with normal versus reduced LV systolic function as the cause of their congestive heart failure symptoms and signs. It is clear that FCU is superior to traditional bedside evaluation, including physical examination, EKG, chest X-ray, and blood analysis for the detection of LV systolic dysfunction in patients with ADHF.[58] Although these patients all need comprehensive echocardiography, the bedside use of FCU allows earlier knowledge of LV systolic function, which allows both initiation of appropriate therapies and avoidance of contraindicated therapies before the complete echocardiogram is done and reported. In 1 study of patients with ADHF, FCU allowed directed therapy to start 18 hours (on average) before a complete echocardiogram was performed and formally reported.[58] Another trial demonstrated reduced length of stay when a hospitalist used FCU to guide ADHF care.[67]

b. FCU When Echocardiography is Not Practical

i. Frequent serial examinations to follow up an ultrasound finding

Very few echocardiographic parameters are worthwhile for assessing every day or multiple times a day for a period of time, such as during a hospitalization. It would be impractical to use traditional echocardiography for this purpose. Although a pericardial effusion may need serial assessment, repeated evaluation of this is best reserved for limited TTE not FCU. The knowledge base to interpret the hemodynamic effects of a pericardial effusion is beyond the scope of FCU. In addition, serial comparison of images, which is critical with pericardial effusions, is often difficult with FCU systems. Knowledge of patient volume status (at least as measured by RA pressure), however, is frequently assessed by physical examination and, therefore, suitable for FCU.[68,69] Patients admitted with ADHF should have complete echocardiographic evaluation if it has not been performed recently. These patients may have uncertain volume status after initial diuresis. FCU assessment of the IVC is both more feasible and accurate than physical examination for detecting elevated central venous pressure.[53] Evaluation of IVC size and plethora with FCU has been successfully piloted in patients with ADHF and shown to be a predictor of hospital readmission.[69] Patients in the ICU may have fluctuation in volume status and/or LV or RV function. FCU is readily applicable for use in serially monitoring a patient's volume status and ventricular contractile function in the critical care area.

ii. Physical examination adjunct in at-risk populations

Physical examination may identify subjects who are asymptomatic but have a cardiac condition, but sensitivity is low. Echocardiography (comprehensive or limited) is not practical or reimbursed when used as an adjunct to physical examination. FCU is potentially an ideal technique to improve physical examination detection of cardiac disease because FCU devices are portable and relatively inexpensive, and nonechocardiographer users can be trained to use them with reasonable accuracy. An appropriate pathology to identify would have the following characteristics:

- Identifiable with FCU
- Somewhat prevalent
- Asymptomatic
- Frequently missed by physical examination
- Associated with significant morbidity
- Effective therapies exist for asymptomatic patients

LV systolic dysfunction (LVSD) is an ideal target. It is reliably identifiable with FCU and is somewhat prevalent, even in a population of asymptomatic subjects (2.0%-4.0%) but is often missed by physical examination and has effective therapy even in the preclinical stage.[70,71] Results of several studies have shown the feasibility of FCU for identifying LV dysfunction in a variety of patient populations.[45,51,58,59,63,64,72-76] A cost analysis study was performed, which suggested that using FCU in patients with an abnormal brain natriuretic peptide or EKG was the most cost-effective strategy for identifying asymptomatic LV dysfunction.[77] However, unlike global LV dysfunction, assessment of regional wall motion may be challenging and is best assessed by echocardiography.

In addition to LVSD, other echocardiographic findings can also identify patients at an increased risk for cardiovascular morbidity and mortality, such as left ventricular hypertrophy (LVH) and increased left atrium (LA) size.[78] Increased LV wall thickness and LA dimensions can be readily identified with FCU.[17,76] It is possible to perform an examination for LV dysfunction, LA enlargement, and LVH from the parasternal long-axis ultrasound view within seconds to a few minutes more accurately than the assessment of sustained apical impulses, or S3 or S4 gallops. Confirmation of LVH and LA enlargement with echocardiographically derived LV mass index and LA volume, which have established prognostic value, is appropriate. Using FCU in this way may also have prognostic implications.[76] The addition of subcostal imaging of the IVC to estimate RA pressure to the parasternal appraisal of LV function and LA size is superior to inspection of the jugular venous pulse and precordial assessment for LVSD and LA

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enlargement.[79] The appropriate setting and patient population for such examinations would need to be studied. Results of preliminary data suggest a reasonable yield in patients at higher risk for CV disease, such as those patients in general medical inpatient wards.[73] Whether the value of adding FCU to part of a routine physical examination could be demonstrated in a healthier general outpatient population remains to be seen.

c. eFCU

In general, an experienced echocardiographer would use an echocardiographic device with complete functionality to image cardiovascular structures. The following situations occur when a level II/III trained echocardiographer with knowledge of comprehensive echocardiography uses a device that does not meet criteria for performing echocardiography. This use model is defined as eFCU. Although not the focus of this guideline, these are briefly described.

i. Adjunct to physical examination

Echocardiographers may find FCU devices useful in their clinical practice in settings similar to other practitioners to supplement their physical examination assessments of patients.

- The need for cardiac ultrasound is emergent or more urgent than when echocardiography is feasible[66,80,81]
- Echocardiography is not immediately available and the findings from FCU would allow early triage and earlier directed clinical management[13,27,28,82-88]
- Frequent serial examinations to follow up an ultrasound finding
- During physical examination of at-risk populations in which there is a clinically relevant abnormality. Given the added expertise in image acquisition and interpretation, eFCU as an adjunct to physical examination has demonstrated the ability to detect LVH,[38,89] LVSD,[77,90] LA enlargement,[90] abdominal aortic aneurysm,[90,91] and carotid plaque.[90]

ii. Assessing heart disease in underserved or remote populations in which echocardiographic platforms are not available

The underserved population often have no or limited access to echocardiographic evaluation. Having an echocardiographer evaluate underserved patients with a small ultrasound device at the point of care opens a new vista for making diagnoses in patients who either have a long wait to get an echocardiogram at a public health facility (county hospital) or are unable to afford an echocardiogram.[72] Small ultrasound platforms have been used to identify significant myocardial disease such as LVH, reduced left ventricular ejection fraction, and valvular and congenital heart disease. This methodology has also been successfully used to image patients in remote locations.[92-97]

iii. Screening of athletes for potential causes of sudden cardiac death

Screening of at-risk populations in which there is a low incidence of positive findings is another example in which a small device might provide a lower cost option to evaluate otherwise healthy individuals. An example of this type of screening would be the screening of athletes for potential causes of sudden cardiac death.[98,99] An eFCU may allow identification of hypertrophic cardiomyopathy, which is the most common cause of sudden death in this population. In this context, this is eFCU (not FCU) because the expertise in imaging and the expertise in image interpretation (to diagnose hypertrophic cardiomyopathy) are substantial.

d. FCU Imaging Protocol

The specific views to obtain and images to acquire may differ, depending on the clinical need,. At this point, a universal FCU examination cannot be proposed. Factors to consider when designing an FCU protocol include

- The limited functionality of hand-carried devices
- Image acquisition skills of the examiner
- Interpretation skills of the examiner
- Disease states, given the device capabilities, image acquisition expertise, and interpretive training expertise that can be reliably detected
- Pathologies that need to be confirmed and/or excluded given the clinical question

Some FCU clinical use models may only require 2D imaging. Although nonechocardiographer users can be taught to perform a color-Doppler examination, the clinical scenarios in which FCU has proven useful do not generally require use of color Doppler and spectral Doppler. There are very few situations in which the need to know about a regurgitant valvular lesion is more urgent than when echocardiography is feasible or requires frequent serial examination that would be impractical for echocardiography. If an FCU clinical need were identified for Doppler, then the expertise to use these Doppler techniques responsibly would require additional didactic education, hands-on imaging, and maintenance of competency.

FCU extended physical examination may be performed primarily from the parasternal and subcostal acoustic windows, which is consistent with 2 published ultrasound examinations that involve cardiac imaging as a part of their protocols. Both the Cardiopulmonary Limited Ultrasound Exam (CLUE) and Focused Abdominal Sonography in Trauma (FAST) examinations image the heart from the parasternal and subcostal windows only. As reviewed above, the expertise to acquire images from these windows is significantly less than apical views. When assessing LV systolic function, there is a theoretical consideration that extensive apical abnormalities may not be appreciated if imaging is performed only from the parasternal window. Several studies have demonstrated that parasternal imaging is adequate for the subjective assessment of LV function.[17,58,60,74,75,82,90] Imaging from subcostal and parasternal windows also requires minimal or no patient positioning or cooperation, which is key in many of the clinical scenarios in which FCU is likely to be useful.

There may be cases in which an apical window may be the only window that gives useful images. It may be more prudent to wait for formal echocardiographic imaging than trying more difficult windows to avoid the hazards of off-axis apical imaging. Apical imaging can easily lead to overestimation of left ventricle ejection fraction by foreshortening and to a false conclusion of RV dilatation by obtaining an RV modified apical 4-chamber image rather than a true apical 4-chamber image. However, FCU use models may be developed in which the apical views are required. If apical imaging is needed, then it should be included in the training (didactic, hands on, and interpretive). It is imperative to recognize that imaging from additional views and acquiring supplemental images does not change an FCU augmented physical examination into an echocardiographic examination. The difference between these techniques lies in the expectations of the examination, the equipment used, the expertise in image acquisition and proficiency in data analysis and interpretation (section 3.), not in the number of images acquired, patient position during examination, or windows from which imaging was performed.

Depending on the specialty of the practitioner, FCU may only be a portion of a specialty's bedside ultrasound protocol. For example, the FAST examination in trauma involves ultrasound of the heart, chest, abdomen, and pelvis. Imaging in the critical area may include noncardiac targets, such as lung water, ascites, hydronephrosis, and

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pleural effusions. This guideline is not meant to cover extracardiac imaging protocols. It would be expected that multiorgan protocols that involve cardiac imaging would adhere to the guidelines set forth for the cardiac portion of their imaging protocol. One could imagine modules of training for different aspects of bedside ultrasound use.

e. Quantification

Quantitative assessment is a core component of echocardiography, whether complete or limited. There are detailed documents about how to properly measure the cardiac chambers, ventricular performance, valvular lesions, and vessels.[7,9-12] Devices used for FCU imaging have a variable degree of measurement capabilities. These devices have shown reasonable accuracy when used by novices to quantify LVH, LA size, and LV dimensions.[47,50,100] However, making measurements has several disadvantages during FCU. Learning how to make even basic measurements adds to the duration of didactic and practical training. Pausing during a bedside assessment to quantify the size of a cardiac structure or to compute a calculation adds delay to a procedure for which rapid bedside evaluation is one of its major strengths. The lack of an ECG gating with some FCU devices increases the chance of making an inaccurate measurement. Lastly, for the scope of practice in which FCU has been used, quantification is simply not necessary.

The bedside decisions facilitated by FCU can generally be made by using subjective categorization of abnormalities into broad ranges of severity. Knowing if LV systolic function is normal, reduced, or severely reduced allows immediate therapeutic decisions to be made in a patient admitted with ADHF. Most clinicians would like to know if a pericardial effusion and RV are normal, large, or very large rather than a quantitative measurement. The LA has well-documented subjective interpretation criteria that correlate well with criterion standards.[52,101]

f. Image Archival and Reporting

Devices currently used for FCU examinations all store images internally. The storage format varies from device to device, as does the ease of image integration with enterprise digital storage systems. The documentation (both image and report) of FCU examinations is dependent on clinical use. The writing group's recommendation is that images performed to evaluate a symptomatic patient to direct management because formal echocardiography is not available should be stored to a retrievable location. Ideally, this would be on the same digital storage system where the clinical echocardiography images are stored. Storage of these images is useful for both quality assurance (for the FCU clinician) and for assessment of changes by comparison with the formal echocardiographic findings.

All FCU examination results must be documented in the patient chart and/or electronic medical record. Parameters should include the same items recorded for a physical examination:

- Date and time of examination
- Name and hospital identification number of the patient
- Patient age, date of birth, and sex
- Name of the person who performed and/or interpreted the study
- Findings

If the FCU examination is noted within the physical examination portion of the chart, then most of these items are likely present and only the findings need to be documented.

Studies performed to evaluate a symptomatic patient to direct management because formal echocardiography is not available, should, in addition, include the following:

- Indication for the study
- Impression (including when a study is nondiagnostic)
- Mode of archiving the data (where can the images be found to be viewed)

Images from an FCU examination performed for serial evaluation of the IVC or ventricular function in a patient with a prior comprehensive echocardiogram need not be saved. Ideally, significant changes in serial findings would prompt referral for limited echocardiography. Images performed as part of an extended physical examination in a patient at risk for cardiac disease (but no cardiac symptoms) need not be saved either, but abnormal findings should prompt referral for echocardiography. This is consistent with current cardiac physical examination techniques such as inspection, palpation and auscultation, the presence or absence of signs are documented but without mandatory recording of pictorial, video, or audio information despite the modern capability to do so. The findings from FCU in these settings should be formally documented in the patient's chart. The results of FCU can be easily recorded within the physical examination portion in the medical record, akin to the handling of visual bedside information obtained through use of the ophthalmoscope or otoscope, thereby setting appropriate physician and patient expectations of this bedside technique. Mandatory video archival and formal reporting of FCU examinations for these indications would unnecessarily increase the time needed for examination and create an unnecessary burden on digital storage within the electronic health record.

6. TRAINING RECOMMENDATIONS

The development of FCU devices offers the opportunity to provide a quick snapshot view of the heart at the bedside. Although the devices and protocols are less complex than standard echocardiography, the training and oversight required to develop the skills necessary to perform and interpret FCU studies must not be minimized. Although specific training requirements (duration, number of studies, etc) are not offered, this document provides a framework from which the medical community can establish the criteria necessary to optimize the use of this exciting new technology.

There are a number of articles that demonstrate acceptable accuracy of nonechocardiographer users who performed FCU from which one could surmise that the training protocol used was adequate.[30,45,48-56,58,59,63-65,72-75,102] However, the heterogeneity in these studies makes it difficult to draw specific conclusions. The training protocols differed with respect to the background of the trainees, the ultrasound device used, the hours and content of didactic lectures, acoustic windows imaged from, the number of ultrasound examinations performed, percentage of proctored examinations, subjects imaged (volunteers, patients), clinical setting (echocardiography laboratory, ward, clinic, ICU), which cardiac findings were evaluated (LV function, atrial size, etc), whether assessment was subjective or quantitative, and the criterion standard used. Studies that evaluated the acquisition of FCU skills by novice users (residents) found an "acceptable" level of skill in performing and interpreting FCU studies might be obtainable with 20-30 studies if the scope of acquisition and interpretation were limited.[47,103]

Although there may be a perception that FCU examinations are "easier" to perform, this is not necessarily the case. It is true that there

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are fewer controls and settings to master. An FCU examination involves a reduced number of windows and can be performed without knowledge of more advanced ultrasound technologies (Doppler, strain, 3D, etc). However, one should also take into account that the transducers might require extra skill due to their limited processing power, poorer penetration, and lower number of scanning elements, which results in a more challenging proposition to obtain clear images. The size and quality of the screens on FCU systems are inferior compared with full-size systems, and they may be more sensitive to viewing angle and light conditions. It is also inopportune that the clinical situations in which an FCU examination might prove most useful are frequently settings that have subjects with the poorest acoustic windows. ICU settings with limited patient mobility and possibly mechanical ventilation are difficult to image even by skilled echocardiographers.[104] Trauma, drains, and bandages in patients who are acutely ill can limit image acquisition even with full-featured platforms.

a. Background

Although training for FCU can begin in medical school, FCU use should be limited to licensed physicians. It is expected that physicians with diverse training backgrounds could use FCU in patient care. The scope of this document is limited to the use of FCU in the care and management of adult patients, and, therefore, physicians should be trained in an adult medical or surgical specialty. By nature, FCU technology is used at the patient bedside during clinical evaluation and management, so practitioners in radiology are not addressed in this document. It is our recommendation that physicians who have completed training in internal medicine, hospital medicine, emergency medicine, anesthesia, critical care medicine, or cardiovascular surgery would have an appropriate background to pursue training in FCU.

b. Training Environment

A formal structured training program is the best approach to equip physicians with the necessary knowledge and technical skills to perform FCU. Instruction in an FCU course or program should focus not only on providing education but also on assessing competency. Clinicians who seek FCU training should do so within an accredited graduate medical education or continuing education program. It appears feasible and appropriate to begin FCU training in medical school curriculums, where it can be taught in conjunction with history and physical examination training. Bedside ultrasound evaluation, including FCU, may become part of a core curriculum for resident training. To better ensure success, FCU educational programs should collaborate locally with an Intersocietal Commission for the Accreditation of Echocardiography Laboratories accredited echocardiography laboratory. Although portions of training may be done at courses and online, collaborating with certified sonographers and the National Board of Echocardiography certified echocardiographers offers the opportunity to be trained and supported by experts in comprehensive echocardiography. The exposure to the breadth of pathology required to gain experience is best acquired when there is access to the volume of cases performed in a busy laboratory. The quality assurance procedures in place at an accredited echocardiography facility can be expanded to provide oversight for an FCU program.

c. Components of a Training Program - Didactic Education

Recommendations for cardiac ultrasound training for nonechocardiographers include 3 core components: didactic education, hands-on image acquisition, and image interpretation experience. There are important considerations in each of these areas that prior guidelines have not comprehensively addressed.

Guidelines should be specific in the knowledge component of FCU training. Background topics should include ultrasound physics and basic cardiac anatomy with the corresponding ultrasound views. The pathophysiology of the common clinical conditions in the trainee's scope of practice should be reviewed, specifically with regard to the effects these conditions have on cardiac function and structure. Clinical topics will be tailored to the users but should include appropriate clinical use scenarios and imaging protocols. This component is the integration of the cardiac anatomy, pathophysiology with the FCU imaging capabilities, and scope of practice. The indications for FCU versus comprehensive and/or limited echocardiography should be reviewed. Practitioners should get a solid understanding of the appropriate scope of practice by understanding the limitations of FCU imaging equipment as well as the scope of their image acquisition and interpretation training. The value of FCU in specific clinical scenarios should be demonstrated by using case studies and image correlations. Common abnormalities encountered with FCU should be reviewed.

In an effort to accommodate a trainee's limited schedule, the didactic contents of the training could potentially be delivered as hybrid learning modules with a combination of traditional class lectures and online interactive modules. The online module should have a posttest component to ensure that all trainees are prepared for hands-on practice. For spatial training, the use of imaging aids such as 3D cardiac models, phantom imaging, and simulation mannequins may expedite the understanding of scanning planes and their corresponding anatomy. Review of digital-video loops and still frames of normal cases, which show the recommended scanning views and normal variants should be included. The trainee should be familiarized with different chest conformations and possible deviations from the typical scanning windows.

It is important to complete this portion of the training before proceeding to hands-on experience to allow the participant to become familiar with terminology, probe orientation, and views. To maximize the value of the didactic training, the hands-on practice should proceed within a reasonable period of time. Extending the training period outside a predetermined window would be deleterious to competency outcomes.[47]

d. Components of a Training Program - Hands-on Training

There is significant variation in the consideration of cardiac ultrasound simulation as a viable alternative to hands-on training. It is the opinion of this writing group and the ASE that, although ultrasound simulators may be used as adjunct in FCU training, the majority of hands-on studies should be performed on human subjects. There is simply no adequate way to simulate the wide range in patient body habitus, chest wall structure, translational motion of the heart due to respiration, heart orientation within the chest, cardiac size, patient cooperation, and normal variants with simulation.

Training with normal subjects is common in FCU training settings. The use of normal volunteers and/or having trainees image each other serves as a quick way to gain hands-on experience. It is the opinion of this writing group and the ASE that the majority of hands-on image experience be acquired in patients, preferably in the clinical arena where the physician practices or in subjects similar to those in the physician's practice setting. Initially, imaging in normal subjects who have excellent windows and are cooperative in their positioning and respiration is a good way to learn acoustic windows, imaging

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planes, transducer manipulation, and basic anatomy. However, experience imaging at the bedside in real-life settings is invaluable.

There is ambiguity in how the hands-on experience should be supervised in other guidelines. It is the recommendation of this writing group that a portion of hands-on studies be proctored in real time. Immediate feedback while acquiring images from an experienced imager is critical to success. Acquisition of images in the presence of a proctor and independent acquisition of images are both necessary experiences.

Although most guidelines recommend independent image acquisition as a core component of training, there is often ambiguity in the setting in which this occurs. The ASE recommends that a significant number of examinations should be performed with the device (or device with similar capabilities) that the physician will be using for FCU and performed on patients in clinical settings typical of the trainee's scope of practice. Training with a full-featured device on selected stable outpatients, for example, does not prepare a clinician to image patients who are critically ill and intubated with a small portable bedside device.

Lastly, most guidelines fail to specify the equipment requirement used for hands-on training. It is recommended that the majority of hands-on image cases be acquired with the device (or a device with similar capabilities) that the physician will be using for FCU examinations. Initial experience in an echocardiography laboratory on a high-end platform may prove useful to gain confidence and acquire familiarity with acoustic windows; however, experience must be primarily acquired with the device that will be used for FCU imaging.

e. Components of a Training Program - Image Interpretation

Trainees should keep records of documented cases where he or she performed the FCU protocol and prepared a complete interpretation. A practitioner proficient in FCU or echocardiography should review these scans. Any discrepancy of interpretation should be communicated to the trainee as part of an ongoing learning experience. This could be done at the local institution where a qualified reviewer is involved, or images could be sent to a central reviewing body. All images (loops and frames) stored for review should be deidentified and comply with the Health Insurance Portability and Accountability Act regulations if submitted to an external reviewer. They should be able to recognize the abnormalities and normal structures within the scope of their FCU practice.

It is clear that the variety of pathologies experienced during hands-on training and expert review is likely to be a subset of the scope of pathologies and normal variants seen in the clinical setting. Review of additional cases is essential. Ideally, this should be provided through didactic review of images or in a self-education review of images selected to represent normal variants and pathologies relevant to the scope of practice. Salient features of the images should be provided with teaching points. Specific lists of cases and/or abnormalities could be developed to represent the normal variants and expected pathologies within a variety of FCU scopes of practice.

f. Documentation and Maintenance of Competency and Quality Assurance

Specific recommendations for documentation of competency cannot be made at this time. Once formal training recommendations are developed, presumably, documentation of competency will involve documentation of the completion of the core components of a training program (didactic education, hands-on imaging, and interpretive skill). There are no current objective metrics or validated tools to determine competency in FCU. Current guidelines and training requirements are based on hours or months in training and the number of ultrasounds performed and/or interpreted, which are used as surrogates of competency.[105-109] There unfortunately is a weak correlation between the number of studies interpreted and the months of training with interpretation accuracy.[110] The correlation between cardiac studies scanned with interpretation and scanning abilities is better, which supports a curriculum that is replete with practical hands-on imaging. Other work has demonstrated that acquisition skills were acquired more slowly than interpretive skills.[47] An FCU training program should emphasize safety and require ample hands-on training and exposure to pathology before considering an individual without echocardiography training competent to use these tools appropriately.

Maintenance of competency is a separate issue from the achievement of proficiency. It is well known that skill level declines unless a technique is regularly implemented and reinforced. Continued excellence in FCU requires ongoing performance of FCU, exposure to a variety of clinical situations and pathology, and staying up to date with advances in the field. To maintain scanning and interpretation skills, a minimum number of studies performed annually will need to be determined. FCU practitioners are encouraged to routinely follow up on the complete echocardiographic findings. Likewise, echocardiography laboratories that perform complete echocardiographic examinations and have access to the results of the prior FCU should communicate missed or misinterpreted findings to the FCU practitioner informally through verbal communication. Additional accredited continuing medical education courses or approved self-assessment programs directly related to FCU should also play a role in maintenance of competency.

NOTICE AND DISCLAIMER

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