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ECHOCARDIOGRAPHY (F ASCH AND S COSTA, SECTION EDITORS)

A Review of Echocardiography Training for Internal Medicine Residents: Proposed Goals, Methods, and Metrics

Jennifer Frampton, DO, MPH[1] · Brenton Nash, MD[2] · Salvatore Costa, MD[1]

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Abstract

Purpose of the review Focused cardiac ultrasound (FCU) is a useful bedside tool that is often utilized by internal medicine residents. Multiple studies have shown that FCU adds valuable information beyond the history and physical. No formal recommendations exist regarding which physiologic parameters should be included in FCU, how those parameters should be assessed, or how to adequately train residents in its use. This review highlights the available literature on FCU training for medicine residents and provides in-depth analysis of the existing programs.

Recent findings There is significant variability among FCU training of internal medicine residents.

Summary A standard FCU training protocol should be considered to incorporate this powerful modality throughout the American Post-Graduate Medical Education System. This review offers recommendations for standard training.

Keywords Focused cardiac ultrasound · Transthoracic echocardiography · Internal medicine resident

Introduction

Focused cardiac ultrasound, or FCU (synonymous with handheld cardiac ultrasound, point-of-care cardiac ultrasound, hand-carried ultrasound, quick-look cardiac ultrasound, and ultrasound stethoscope) is a useful bedside tool that can serve as an adjunct to the clinical history and physical examination [1–8]. Additionally, several studies have demonstrated the superiority of FCU to the history and physical in terms of the accuracy of cardiovascular diagnosis [1, 3, 7, 8]. Given the power of this modality, a number of non-cardiology training programs have integrated cardiac ultrasound into their curricula, including emergency medicine residency and critical care fellowship [9, 10]. The idea of expanding such training to internal medicine programs has been discussed for years. Alexander et al. (2004) and Hellmann and colleagues [3] detailed pilot studies focusing specifically on the internal medicine resident population [11, 12]. Their research was promising and demonstrated that with limited training, internal medicine residents could use FCU to determine left ventricular function and assess for pericardial effusion with moderate accuracy [11]. Additionally, residents learned the mechanics of scanning and the process of interpretation at a reasonably rapid rate [13]. Despite the known utility of FCU and the demonstrated ability of medicine residents to learn such skills, the American Board of Internal Medicine has no formal requirements or suggestions to include FCU instruction within medical residencies [14]. Additionally, there are no recommendations regarding what FCU training should entail. However, a number of progressive internal medicine residency programs have incorporated limited ultrasound as a core component of their physical exam [15].

The American Society of Echocardiography (ASE) published recommendations in 2013 that focused specifically on FCU [6]. First, they distinguished FCU from limited TTE. They state that a limited TTE is performed by someone who is level II or III trained in echocardiography with the ability to perform a full echocardiographic study and make adjustments in their study depending on their interpretation. In contrast, a FCU is used to enhance physical examination when the information obtained may change clinical management. The

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✉ Jennifer Frampton, DO, MPH
Jennifer.L.Frampton@hitchcock.org

[1] Section of Cardiovascular Medicine, Heart and Vascular Center, Dartmouth-Hitchcock Medical Center, 1 Medical Center Drive, Lebanon, NH, USA

[2] Section of Internal Medicine, Dartmouth Hitchcock Medical Center, Lebanon, NH, USA

guidelines detail that left ventricular enlargement, left ventricular hypertrophy, left ventricular systolic function, left atrial enlargement, right ventricular enlargement, right ventricular systolic function, pericardial effusion, and inferior vena cava size can be accurately assessed with FCU [6]. However, the recommendations do not suggest a standard training protocol. They do suggest that training for FCU should consist of three core competencies—didactic education, hands-on imaging acquisition, and image interpretation experience. Based on available literature, they also recommend a trainee preform and interpret 20–30 studies to attain reasonable accuracy [6].

In order to characterize some of the training programs already developed, a review of the literature was performed. The details of multiple training programs will be discussed followed by suggestions for the implementation of a uniform process going forward.

Methods

An advanced search within the PubMed online database was performed, using the following key words—echocardiogram, echocardiography, medical resident, and training. Search results revealed 98 publications that were sorted according to "Best Match". The titles and abstracts of the resultant publications were scanned for relevance. The sources and subsequently citing articles of selected works were also examined. Sources were marked for possible inclusion if the title or abstract referred to FCU (or some synonym thereof) and a training program. After extensive examination of the available results, 32 articles were thought eligible for inclusion. These articles were read in full with the following inclusionary and exclusionary criteria applied.

Inclusion Criteria

In order to be included in the review, an article must have detailed observational data on an educational intervention in which internal medicine residents were the participants. The educational intervention being instruction on the acquisition and interpretation of FCU images.

Exclusion Criteria

Articles were excluded from the review if:

1) The article in question did not report on an educational intervention but instead was a review article or editorial [15–19].
2) The study participants were not exclusively medical residents or not easily identifiable as equivalent to medical residents within the USA post-graduate medical education system [1, 7, 10, 12, 20–31].
3) The article's educational intervention did not exclusively include cardiovascular ultrasonography but also other examinations, e.g., abdominal ultrasound [8, 32–34].

After exclusion of all irrelevant articles, seven remained for in-depth discussion [2, 5, 13, 35–38]. Figure 1 displays a graphic representation of the selection process.

Results

In this section, the themes of the educational interventions employed in each study will be discussed. These themes include the clinical question(s) that each imaging protocol aimed to answer (the cardiovascular parameters assessed), image acquisition (the echocardiographic views employed), the nature of the education the residents received, and FCU interpretation (the accuracy of participant interpretation).

Training Question #1: Which Cardiovascular Parameters Are to Be Included?

All of the reviewed studies included in their conclusions that FCU can or should be used as an adjunct to the physical exam. Some authors assert that the bedside study would allow for a more accurate diagnosis compared to traditional history and physical, others feel that a diagnosis could be expedited by the use of FCU, and some claim FCU would aid with both. However, no two studies agreed on which cardiovascular parameters should be obtained with FCU.

Table 1 demonstrates the frequency with which particular parameters were included in training protocols. There was a wide range of imaging goals for these limited cardiac exams.

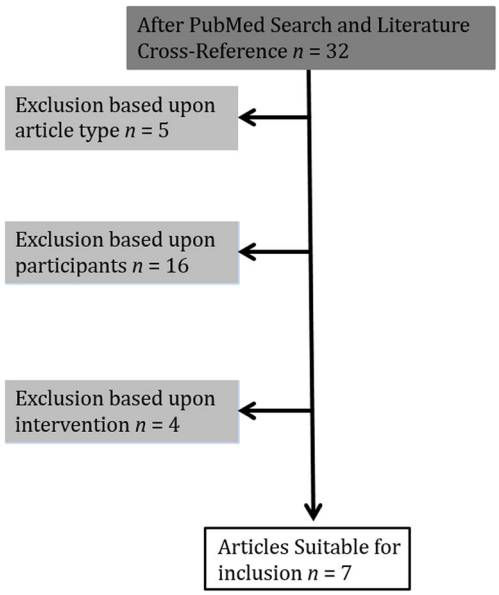

Fig. 1 Representation of the selection process for review of the literature

Table 1 Frequency with which particular cardiovascular parameters were included in training protocols

Cardiovascular parameter	Frequency
Left ventricular function	6
Left atrial size	4
IVC plethora	4
Pericardial effusion	4
Ventricular size	4
Valvular lesion	3
Pulmonary edema/pleural effusion	3

Some studies were highly focused while others were more comprehensive. This is perhaps best illustrated through the comparison between Razi et al., Brennan et al., and Kimura et al. [2, 5, 39] Razi et al.'s participants only visually estimated left ventricular ejection fraction [5]. Equally simplistic was Brennan et al.'s study which only had participants calculate the inferior vena cava collapsibility index [2]. Conversely, Kimura et al.'s participants assessed a multitude of parameters including—the presence of carotid disease, left ventricular systolic function, left atrial size, the presence of pulmonary edema, the presence of pleural effusion, the presence of pericardial effusion, right ventricular size, IVC plethora, and the presence of abdominal aortic aneurysm [36].

Even when a parameter was included in more than one study protocol, the measurement of that parameter varied. For example, for the assessment of left ventricular systolic function, Razi and colleagues required participants merely to visually estimate the left ventricular ejection fraction (LVEF) as being greater than or less than 40% [5]. Other authors that relied on visual estimation to determine left ventricular systolic function included Croft, Mjolstad, and Hellman; however, their scales of assessment differed and did not take the form of < 40% or > 40% [13, 35, 37]. They generally asked participants to stratify patients into one of three groups corresponding with normal, mildly reduced, or severely reduced. Kimura et al. and Tsai et al. both used the E-point of septal separation as a marker of systolic dysfunction [36, 38]. With this measurement, patients were either considered to have "a sign of left ventricular systolic dysfunction" or not.

Training Question #2: Which Echocardiographic Views Should Be Obtained?

As previously mentioned, different investigators prioritized the assessment of different cardiovascular parameters with FCU. These parameters ranged from left ventricular function to the presence of peripheral artery disease. Likewise, the sonographic views through which this physiologic information was assessed also varied. Please refer to Table 2, which illustrates the frequency with which various sonographic views were included in the imaging protocols.

Table 2 Frequency of sonographic views included in the imaging protocols

View	Number of studies
Parasternal long axis	5
Parasternal short axis	4
Inferior vena cava	4
Apical four chamber	3
Apical two chamber	2
Abdominal aorta	2
Lung apices	2
Lung bases	2
Carotid bulbs	1
Sub-costal four	1

Interestingly, residents from different studies in which they learned to acquire more than one sonographic view did not always universally struggle with the same view. Of the studies that assessed the objective accuracy of each view—two demonstrated that residents were the least accurate with the apical two chamber view, while Kimura and collogues demonstrated that the apical four was the hardest for residents to acquire [13, 36, 37]. Subjectively, the residents that took part in Tsai et al.'s study found that they struggled most with the sub-costal view [38].

Conversely, the views that residents acquired with the most easy were the IVC view [36], parasternal short axis [13], and parasternal long axis [37].

Training Question #3: How Should Residents Be Trained?

Interestingly, while previous sections have highlighted the differences in educational programs, there were some commonalities within the actual FCU training residents received. In all studies, residents underwent some didactic education on cardiac ultrasound and expert-supervised hands-on image acquisition experience [2, 5, 13, 35–38]. Most studies also provided additional supplemental resources—in the form of hand-outs, online resources, and audiovisual materials [5, 13, 35–37].

Yet differences still existed, predominately with regard to the amount of didactic education and hands-on experience provided. Some educational programs had as little as 15–30 minutes for didactics and as few as three studies encompassing hands-on experiences [13]. Conversely, others included as much as 15 hours of didactics and as many as approximately 95 studies per resident constituting hands-on experience [35, 37].

Perhaps, the most extensive training program described comes from, Kimura and colleagues, who have worked specifically to determine an optimal training program for internal medicine residents on focused cardiac ultrasound or in their

terms "CLUE" (cardiovascular limited ultrasound examination) [36]. In their proposal of a training protocol, the residents attend 12 monthly 1-h CLUE lectures given per year. Most of the lectures were 30–45 min in length, with the last 15–30 min spent imaging other residents or patient volunteers. In the initial training protocol, the intern (first year medical resident) is expected to image 10–30 patients during their cardiology consult block under the monitoring of sonographers. The training then continues throughout the duration of their residency program. During their time in the ICU and cardiology consult rotations, juniors and seniors (second and third year medical residents) receive 1-h long bedside teaching once a week. They are also expected to image an additional 10–30 patients while on those blocks. The residents also image patients throughout their other clinical care rotations. The goal is that with this training program, the residents will have imaged a minimum of 30 patients. However, some residents conclude their residency with having imaged over 100 patients. In addition, the residents have access to multiple learning aids including videos, a syllabus, self-assessment tests, and an instructional website. The training proposal is certainly one of the longest and arguably most thorough when compared with the other studies. The researchers note that with this training, residents have an 81% pass rate in their cardiovascular limited ultrasound examination competency [36].

Training Question #4: How Is Resident Competency Assessed?

Most of the included studies provided statistics describing the accuracy, sensitivity, and specificity of resident findings on FCU compared to those of expert echocardiographers.

For example, Razi et al., as previously mentioned, had medical residents visually estimate the left-ventricular ejection fractions of patients in acute decompensated heart failure. The residents had to determine if the patient's LVEF was either greater than or less than 40%. The accuracy of residents was assessed by comparing their estimates with the patient's left-ventricular ejection fraction as measured by formal echocardiography [5].

Croft et al. had residents perform FCU on general internal medicine clinic patients. The FCU was observed by a level III echocardiographer who did not offer any feedback or assistance during resident imaging acquisition. After the medical residents completed their examination they filled-out a form that detailed the sonographic views obtained, assessment of LV function, presence of wall motion, presence and grading of valvular lesions, presence of pericardial effusion, assessment of LVH, and if changes to the management strategy were made based on the echocardiographic data. The level III echocardiologist performed the same HCU exam after the resident and filled-out a similar data sheet [37].

Mjolstad et al. in 2013 compared resident-preformed bedside FCU to conventional echocardiography. The correlation between various measurements was calculated [35].

Tsai et al. only preformed a detailed analysis on one resident in their cohort, which included assessment of accuracy. The single resident's diagnoses obtained with FCU were compared with discharge diagnoses and information obtained from various diagnostic studies [38].

Training Question #5: How Accurate Is the Interpretation of the Images that Are Obtained?

Razi et al. found that residents could diagnose left ventricular systolic dysfunction (defined as LVEF < 40%) with a 94% sensitivity and 94% specificity. With sub-group analysis, residents had a 100% sensitivity for LVEFs > 50% and < 30%. They had greater difficulty when differentiating between preserved and reduced ejection fraction when the EF was between 30 and 50% [5].

Croft et al. discovered an overall 93% concordance rate among residents and the expert in terms of echocardiographic diagnosis. With sub-group analysis, the residents identified minor echocardiographic findings (less severe findings) with an 80% sensitivity and a 99% specificity; however, the sensitivity of residents to identify major findings (more severe derangements) increased to 93% and specificity remained the same [37].

In Mjolstadet al., there was a strong correlation between global left-ventricular function, pleural and pericardial effusion, aortic valve disease (stenosis or regurgitation), and abdominal aortic aneurysm on conventional echocardiogram and FCU. There was a moderate correlation for regional left-ventricular function and atrioventricular valve regurgitation. Interestingly, for all variables—LV dysfunction, RV dysfunction, LA enlargement, aortic valve disease, mitral regurgitation, and tricuspid regurgitation, specificity was greater than sensitivity [35].

With Tsai et al's. single analyzed resident, an accuracy of 81% was demonstrated. It is not known which cardiovascular parameters this resident identified with 81% accuracy [38].

Training Question #6: Do Medical Residents Utilize FCU?

It is worth mentioning that the data suggest when internal medicine residents receive formal training in FCU and have access to pocket-sized devices, they will use the devices frequently [38]. A recent study published by Tsai et al. details findings among internal medicine residents trained under the guidance of Kimura and colleagues. The residents receive their formal ultrasound training as a mandatory part of their curriculum. They were then studied while serving as an admitting hospitalist in a large community hospital. Authors found that the residents would autonomously elect to perform the focused cardiac ultrasound exam on a

significant proportion of patients admitted to their hospitalist service (42%). Additionally, there were more likely to be positive findings in patients who were imaged with FCU than those who were not. This indicates that residents use it in a target manner that answers a clinical question based on a pre-test probability [38].

Discussion

The role of FCU remains controversial in both centers with available cardiac ultrasound services and without. However, there is a growing interest in the adoption of this technology in a limited role and thus, standardization of training would likely increase resident success. As previously mentioned, most investigators advocate for the dissemination of FCU as a tool to augment the physical exam. Nearly every study included suggests that with advancing technology, physicians are relying more on advanced diagnostic studies than on physical examination. With the decreasing reliability of the physical examination, there is a desire to have another objective means to quickly and accurately assess cardiovascular parameters.

The studies included have demonstrated that medical residents can obtain and interpret echocardiographic information with reasonable accuracy. While it is true, that no study demonstrated 100% correlation between the residents' findings and those of the expert, one may argue that 100% accuracy is not necessary. With FCU being used to inform diagnosis and treatment decisions rapidly, it follows that only those pathophysiologic processes that are more advanced require rapid identification and intervention. This review would suggest that FCU training currently available allows medical residents to do just that. This is evidenced by the consistent demonstration that resident physicians interpret bedside studies in a very specific (albeit not sensitive) manner [35, 37]. As mentioned previously, the resident's sensitivity decreases when sub-group analysis of minor abnormalities is performed but specificity remains the same. As a result, residents did not miss any major echocardiographic findings [35, 37].

Lastly, the studies suggest that there should be some measure of competence. One possible metric comes from Jozwiak and colleagues. They conducted a study in France in which residents (equivalent to fellows in the USA), who were mostly echocardiographic novices, had their skills assessed by a score the authors developed. The score was based on an accepted trans-esophageal echocardiogram scoring system. The system focused on six TTE views and evaluation of four semi-quantitative measurements including right ventricular dilation, pericardial effusion, respiratory variation in IVC diameter, and left ventricular ejection fraction [31]. The score earned by residents helped to determine if they could identify the correct diagnosis and treatment for patients with acute circulatory failure. Such a scoring system or measure of competence is needed for existing and future internal medicine training programs.

Limitations of this literature review include the small sample sizes of the included studies. Notably, even the recommendation of the ASE to have a resident perform a minimum of 20–30 studies to ensure competency is based on a study of only 30 medical residents [6, 13]. Additionally, it can be difficult to draw conclusions when each study employs such a wide variety of assessments and measures as with those included in the present review. Lastly, there is not literature providing guidance on how physicians should maintain competency after completing initial FCU training.

With regard to future directions, we conclude that greater standardization in investigatory measures is required. All programs detailed in the review tended to include some didactic and practical training. The greatest variability arises in the parameters being measured and the echocardiographic views obtained. It would be helpful for training programs to use a similar framework and a reasonable candidate may be the CLUE examination [39]. Based on our review of the limited literature, we have made some training and protocol suggestions for FCU for novice residents, as demonstrated in Table 3.

Table 3 Suggestions for FCU protocol and training for novice residents based on review of the literature

1) Cardiovascular parameters: review of the literature suggests that internal medicine residents are capable of using FCU to estimate ejection fraction and to evaluate the pericardial space for presence of an effusion [5, 11, 35]. More detailed assessments, such as the evaluation of valvular disease should be left for a formal echocardiography study [11, 35]
   a. Ejection fraction or systolic function estimation
   b. Pericardial effusion
2) Echocardiographic views: residents should attempt to obtain the parasternal long axis and subcostal views; they should not focus on the apical views [13, 36–38]
   a. Parasternal long
   b. Subcostal view
3) Training programs: training programs should consist of some didactic education and expert supervised hands-on image acquisition experience; we are in agreement with the recommendations from the ASE for 20–30 studies to be obtained (supervised) prior to being considered "trained." [13] Training should also be integrated longitudinally throughout the curriculum
   a. Didactic education
   b. Supervised "hands-on" experience
   c. Longitudinal
4) How to define the interpretation of the images: the literature suggests that defining ejection fraction as a categorical variable (normal, mildly reduced, severely reduced) as opposed to estimating an exact number is likely more accurate. Based on goal sensitivity and specificity > 90%
   a. Categorical variables
5) Accuracy of the images: the development of some standardized assessment tool may be warranted as suggested by Jozwiak and collogues [40]. Competence should also extend to correctly integrating the imaging findings into the treatment plan.
   a. Standardized
   b. Integrated into treatment plan
6) Utilization: the literature suggests that it should be utilized when the focused cardiac ultrasound could change the management of a patient

These suggestions are made while recognizing the previously mentioned limitations with regard to the variability in the studies collectively, however attempting to recommend a reasonable starting point for internal medicine residency programs. Notably, the incorporation of point-of-care ultrasound (including cardiac) exams into a non-cardiology training program is not novel and thus other specialties can be looked to for example. Emergency medicine is one such residency program. The Accreditation Council for Graduate Medical Education (ACGME) requires point-of-care ultrasound training be a component of Emergency Medicine Residency. The American College of Emergency Medicine Physicians formulated extensive guidelines for the structure of ultrasound (not exclusively cardiac) training programs for residents [9]. And thus, it may be helpful to work in collaboration with other specialty societies to create a standard document for focused training going forward.

Conclusion

In conclusion, review of the available literature revealed that there is significant variability in the training of internal medicine residents to use FCU. There is variability in the parameters assessed, echocardiographic views obtained, and training programs. Like those studies included in this review, we feel that FCU can be a powerful tool and adjuvant to the physical examination. In order to promote the incorporation of such training into internal medicine residency, greater standardization should be considered. This review offers recommendations for such standardized training.

Compliance with Ethical Standards

Conflict of Interest All authors declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- •• Of major Importance

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