Brief Group Training of Medical Students in Focused Cardiac Ultrasound May Improve Diagnostic Accuracy of Physical Examination

Thomas M. Stokke, Vidar Ruddox, MD, Sebastian I. Sarvari, MD, PhD, Jan E. Otterstad, MD, PhD, Erlend Aune, MD, PhD, and Thor Edvardsen, MD, PhD, FESC, Oslo and Tønsberg, Norway

Background: Physical examination and auscultation can be challenging for medical students. The aim of this study was to investigate whether a brief session of group training in focused cardiac ultrasound (FCU) with a pocket-sized device would allow medical students to improve their ability to detect clinically relevant cardiac lesions at the bedside.

Methods: Twenty-one medical students in their clinical curriculum completed 4 hours of FCU training in groups. The students examined patients referred for echocardiography with emphasis on auscultation, followed by FCU. Findings from physical examination and FCU were compared with those from standard echocardiography performed and analyzed by cardiologists.

Results: In total, 72 patients were included in the study, and 110 examinations were performed. With a stethoscope, sensitivity to detect clinically relevant (moderate or greater) valvular disease was 29% for mitral regurgitation, 33% for aortic regurgitation, and 67% for aortic stenosis. FCU improved sensitivity to detect mitral regurgitation (69%, \( P < .001 \)). However, sensitivity to detect aortic regurgitation (43%) and aortic stenosis (70%) did not improve significantly. Specificity was \( \geq 89 \)% for all valvular diagnoses by both methods. For nonvalvular diagnoses, FCU’s sensitivity to detect moderate or greater left ventricular dysfunction (90%) was excellent, detection of right ventricular dysfunction (79%) was good, while detection of dilated left atrium (53%), dilated right atrium (49%), pericardial effusion (40%), and dilated aortic root (25%) was less accurate. Specificity varied from 57% to 94%.

Conclusions: After brief group training in FCU, medical students could detect mitral regurgitation significantly better compared with physical examination, whereas detection of aortic regurgitation and aortic stenosis did not improve. Left ventricular dysfunction was detected with high sensitivity. More extensive training is advised.

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Keywords: Focused cardiac ultrasound, Pocket sized, Physical examination, Diagnostic accuracy, Medical students

Although patient history and physical examination, including auscultation, remain the basis of the initial assessment of a cardiac patient, the limited diagnostic accuracy of the stethoscope is well known. In recent decades, the emerging field of portable ultrasound has challenged the use of the stethoscope. The recent arrival of pocket-sized devices facilitates true bedside routine use and has created a new paradigm for the use of ultrasound. The concept of focused cardiac ultrasound (FCU) has been introduced. Despite their small size and limited features, pocket-sized scanners have proven diagnostic value when used as an adjunct to physical examination by experienced echocardiographers. Low cost and simplified operation have opened their potential use to nontraditional cardiac ultrasound users, and a growing body of evidence suggests that inexperienced operators also improve bedside diagnosis with such scanners. However, the amount of training required to reach a given and standardized level of accomplishment is still a matter of debate. The prospect of educating and training all physicians represents an enormous challenge, and the demand for cost-effective training programs may gain in importance.

Few studies have thus far evaluated the use of the pocket-sized FCU devices in a large group of medical students. Our aim with the present study was to investigate whether a brief, group-based FCU training course would allow medical students to improve their ability to detect clinically relevant cardiac lesions at the bedside.
of 72 elective patients already referred for routine echocardiographic examinations were included in the study, which was conducted in the Department of Cardiology, Oslo University Hospital, Rikshospitalet (Oslo, Norway), between February and May 2012. All patients who were available during the days of inclusion were asked to participate. Exclusion criteria included practical and medical considerations, such as lack of consent, shortage of time between scheduled procedures, and postprocedural or hemodynamically unstable patients. Written informed consent was obtained from all participants, including patients and students. The study was approved by the Regional Committee for Medical Research Ethics and conducted according to the second Declaration of Helsinki.

Echocardiographic Training

Before attending the training course, the students were encouraged to study a selection of echocardiographic loops provided online, demonstrating normal cardiac anatomy and common pathologies. The precourse material also featured a compendium describing the cardiac views in ultrasound and instructions on how to position the transducer to obtain the different views. The course for six trainees at a time (pilot group of three) consisted of a 45-minute introduction to cardiac ultrasound with a review of the same echocardiographic loops that were provided online. The loops demonstrated (which were recorded with an FCU device) are summarized in Table 1 and included both normal cardiac anatomy and common pathologies. In addition, the FCU examination protocol was demonstrated in practice, with emphasis on scanning technique to obtain the cardiac views and the evaluation criteria for each parameter (Table 2). After the initial session, the students were given 60 minutes to practice on one another, to familiarize themselves with the device and to practice obtaining all images according to the protocol. Each student examined two other students. Furthermore, the students had 75 minutes of practice on patients in the cardiology ward. These patients were selected for cardiac pathology. Two students examined each patient together, and each student pair examined two different patients. This was followed by 60 minutes of case reviews, in which the recorded images from the ward patients were discussed and compared with a standard echocardiogram. The students thus were challenged in image interpretation. Training in electrocardiographic interpretation and auscultation was not involved, as these skills had been taught in the clinical curriculum.

Data Analysis

As suggested by the Standards for Reporting of Diagnostic Accuracy statement, diagnostic accuracy was calculated in terms of sensitivity, specificity, positive and negative predictive value, and \( \kappa \) values. A cardiac lesion was defined as clinically relevant when it was moderate or greater in severity, which routinely leads to an additional evaluation by standard echocardiography. In addition to presenting accuracy data with the cutoff for clinically relevant lesions at moderate or greater, results from valvular diagnoses are also presented with the cutoff at mild or greater pathology to show the total number of detected lesions.

To compare accuracy among the students, we developed a diagnostic scoring system modified from Decara et al. and Panoulas et al. For each true-positive finding of a significant cardiac lesion, two points were given. For each true-negative finding of a mild lesion, one point was given. For each true-negative or normal finding, 0.5 points were given. For each false-negative finding, zero points were given. For each false-positive finding, 0.5 points were deducted. In cases of underestimation of a lesion (student reports mild when truly moderate or severe), 0.5 points were still given. In cases of overestimation (student reports moderate or severe when truly mild), 0.5 points were still given. To calculate the diagnostic score, the total score obtained by the student was divided by the maximum score possible.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>Aortic regurgitation</td>
</tr>
<tr>
<td>AS</td>
<td>Aortic stenosis</td>
</tr>
<tr>
<td>FCU</td>
<td>Focused cardiac ultrasound</td>
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<tr>
<td>LV</td>
<td>Left ventricular</td>
</tr>
<tr>
<td>MR</td>
<td>Mitral regurgitation</td>
</tr>
</tbody>
</table>

Methods

Study Population

In this prospective study, 21 medical students from the University of Oslo, all in their second half of medical school and without prior echocardiographic experience, were randomly recruited from 104 applicants to complete a standardized 4-hour FCU training program. A total

Echocardiographic Equipment and Methods

The FCU examination was performed with the Vscan (GE Vingmed Ultrasound AS, Horten, Norway). The device is handheld, fits in the pocket, and consists of a display unit (135 × 73 × 28 mm) and a broad-bandwidth phased-array probe (120 × 33 × 26 mm; frequency, 1.7–3.8 MHz). Other specifications include a 3.5-inch flip-up display (resolution, 240 × 320 pixels), a total weight of 390 g, and approximately 60 minutes of scanning time. The scanner provides grayscale two-dimensional imaging and color Doppler imaging, automatic gain adjustment, and automatic detection of a full heart cycle for storage without the need for electrocardiography. Basic measurements can be performed using the provided caliper tool.

Standard echocardiography was performed in the hospital’s echocardiography laboratory by experienced cardiologists, with the high-end Vivid E9 or Vivid 7 scanner (GE Vingmed Ultrasound AS). The investigators were blinded to the result of the FCU examinations. Data were digitally stored for offline analysis using dedicated software (EchoPAC; GE Vingmed Ultrasound AS). The evaluation criteria for the two echocardiographic methods are shown in Table 2.

Data Analysis

As suggested by the Standards for Reporting of Diagnostic Accuracy statement, diagnostic accuracy was calculated in terms of sensitivity, specificity, positive and negative predictive value, and \( \kappa \) values. A cardiac lesion was defined as clinically relevant when it was moderate or greater in severity, which routinely leads to an additional evaluation by standard echocardiography. In addition to presenting accuracy data with the cutoff for clinically relevant lesions at moderate or greater, results from valvular diagnoses are also presented with the cutoff at mild or greater pathology to show the total number of detected lesions.

To compare accuracy among the students, we developed a diagnostic scoring system modified from Decara et al. and Panoulas et al. For each true-positive finding of a significant cardiac lesion, two points were given. For each true-negative finding of a mild lesion, one point was given. For each true-negative or normal finding, 0.5 points were given. For each false-negative finding, zero points were given. For each false-positive finding, 0.5 points were deducted. In cases of underestimation of a lesion (student reports mild when truly moderate or severe), 0.5 points were still given. In cases of overestimation (student reports moderate or severe when truly mild), 0.5 points were still given. To calculate the diagnostic score, the total score obtained by the student was divided by the maximum score possible.
Quality Assessment

For the purpose of assessing feasibility and image quality, two experienced echocardiographers retrospectively reviewed all recorded FCU images and standard echocardiograms in a blinded fashion and categorized each examination as good, fair, or poor. Note that examinations already deemed inadequate by the students were omitted (n = 2). To be classified as good, all four chambers along with the mitral, aortic, and tricuspid valves had to be visualized from both apical four-chamber and parasternal long-axis views. For valvular assessment, loops of all three valves both with and without color Doppler had to be available. For the grading of fair, a prerequisite was satisfactory imaging of the entire left ventricle and left-sided heart valves, even if only apical or parasternal views were recorded. In case of inadequate or blurred image quality of both or only one view, the examination was classified as poor. A criterion for including poor quality recordings was that the left ventricle could be visualized for functional assessment.

In addition, two experienced echocardiographers interpreted the FCU images recorded by students to separately assess the students’ interpreting abilities. The accuracy of expert interpretations was compared with student accuracy.

Table 1  Cardiac pathologies demonstrated during the training course

<table>
<thead>
<tr>
<th>Cardiac pathology</th>
<th>Imaging mode</th>
<th>Cardiac views</th>
<th>Severity levels demonstrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV dysfunction</td>
<td>Grayscale</td>
<td>PLAX, A4C</td>
<td>Normal (EF, 60%), moderately impaired (EF, 45%), and severely impaired (EF, 30%)</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>Grayscale</td>
<td>PLAX, A4C</td>
<td>Mild, moderate, and large pericardial effusion</td>
</tr>
<tr>
<td>MR</td>
<td>Color Doppler</td>
<td>PLAX, A4C</td>
<td>None, mild, moderate, and severe regurgitation</td>
</tr>
<tr>
<td>AR</td>
<td>Color Doppler</td>
<td>PLAX, A5C</td>
<td>None, mild, moderate, and severe regurgitation</td>
</tr>
<tr>
<td>AS</td>
<td>Grayscale and color Doppler</td>
<td>PLAX, A5C</td>
<td>None, mild aortic sclerosis, moderate stenosis, and severe stenosis</td>
</tr>
<tr>
<td>TR</td>
<td>Color Doppler</td>
<td>PLAX, A4C</td>
<td>None, mild, moderate, and severe regurgitation</td>
</tr>
<tr>
<td>RV dysfunction</td>
<td>Color Doppler</td>
<td>PLAX, A4C</td>
<td>None, mild, moderate, and severely impaired</td>
</tr>
<tr>
<td>Left atrial dilation</td>
<td>Grayscale</td>
<td>PLAX, A4C</td>
<td>Normal, moderately impaired, and severely impaired</td>
</tr>
<tr>
<td>Right atrial dilation</td>
<td>Grayscale</td>
<td>PLAX, A4C</td>
<td>None, dilated</td>
</tr>
<tr>
<td>Aortic root dilation</td>
<td>Grayscale</td>
<td>PLAX, A4C</td>
<td>None, dilated</td>
</tr>
</tbody>
</table>

A5C, Apical five-chamber view; A4C, apical four-chamber view; EF, ejection fraction; PLAX, parasternal long-axis view; RV, right ventricular; TR, tricuspid regurgitation.

Table 2  Echocardiographic landmarks and evaluation methods by FCU and standard echocardiography

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Evaluation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV systolic function*</td>
<td>Visual assessment by observing endocardial motion, overall LV cavity size, and mitral valve excursion, reported as normal, moderately impaired, or severely impaired</td>
</tr>
<tr>
<td>Pericardial effusion*</td>
<td>By caliper in end-diastole, reported as none, moderate (≥0.5 cm), or severe (≥1.0 cm)</td>
</tr>
<tr>
<td>MR*</td>
<td>Visual assessment of the color flow regurgitant jet, reported as none, mild, moderate, or severe</td>
</tr>
<tr>
<td>AR*</td>
<td>Valve morphology, color flow regurgitant jet, vena cava width, PISA method, CW regurgitant profile, pulmonary vein flow (MR), peak E velocity (MR), pressure half-time (AR), diastolic flow reversal in descending aorta (AR)</td>
</tr>
<tr>
<td>AS*</td>
<td>Visual assessment of the color flow jet and presence of calcified aortic ring or aortic cusps with reduced opening, reported as none, mild, moderate, or severe</td>
</tr>
<tr>
<td>TR*</td>
<td>CW Doppler measurements of maximal velocity and mean pressure gradient, including the aortic valve area estimated by the continuity equation</td>
</tr>
<tr>
<td>RV systolic function*</td>
<td>As described for MR</td>
</tr>
<tr>
<td>Left atrial dilation</td>
<td>Visual assessment, reported as normal, moderately impaired, or severely impaired</td>
</tr>
<tr>
<td>Right atrial dilation</td>
<td>RV fractional area change, considered normal (≥32%), moderately impaired (31%–18%), or severely impaired (≥17%)</td>
</tr>
<tr>
<td>Aortic root dilation</td>
<td>Atrial area; normal (&lt;20 cm²) or dilated (≥20 cm²)</td>
</tr>
</tbody>
</table>

A4C, apical four-chamber view; CW, continuous-wave; EF, ejection fraction; PISA, proximal isovelocity surface area; RV, right ventricular; TR, tricuspid regurgitation.

*Clinically relevant when moderate or greater.
Statistical Analysis

Numeric data are presented as mean ± SD or, as appropriate, median (interquartile range) and categorical data as numbers and percentages. Sensitivity, specificity, and positive and negative predictive value were calculated using binary variables and are presented as percentages with 95% confidence intervals. The following statistical analyses were performed using SPSS version 20 (IBM, Armonk, NY): \( \chi^2 \) tests were used to assess differences in categorical variables. McNemar’s tests were used to compare the sensitivities of the two diagnostic methods. Two-tailed \( P \) values < .05 were considered significant. Cohen’s \( k \) coefficients were used to measure interrater agreement for categorical variables. Kappa values < 0.2 were interpreted as indicating slight, 0.21 to 0.4 fair, 0.41 to 0.6 moderate, 0.61 to 0.8 good, and 0.81 to 1.00 very good agreement.\(^{19}\)

RESULTS

In 72 patients, 110 FCU examinations were conducted. In 25 of the patients, repeat evaluations were performed by two to five students. The mean age of the patient population was 65 ± 16 years, with 52 (72%) men. The mean time required for physical examination was 6 ± 2 minutes. Cardiac murmurs were present in 63 patients (57%), as reported by the students. Of these, 50 (79%) were systolic, eight (13%) were diastolic, and five (8%) were combined systolic and diastolic murmurs. The mean FCU examination duration was 17 ± 6 minutes. The median time period between standard echocardiography and FCU was 0 days (interquartile range, 0–4 days).

Diagnostic Accuracy

Figure 1 presents the number of patients who were diagnosed with any form of clinically relevant valvular lesion by the different screening methods. Significantly more cases were detected by standard echocardiography than by stethoscope and FCU (\( P < .001 \) and \( P = .004 \), respectively), but there was no difference between stethoscope and FCU (\( P = .274 \)).

Table 3 presents diagnostic accuracy for the stethoscope and FCU examinations. The overall pooled sensitivity to detect clinically relevant valvular disease with a stethoscope was 40%, which improved to 64% after FCU examination (\( P < .001 \)). With a stethoscope, sensitivity was 29% to identify clinically relevant (moderate or greater) MR, 33% for AR, and 67% for AS. Adding the FCU examination greatly improved sensitivity to detect MR (69%, \( P < .001 \)). However, sensitivity to discover AR (43%) and AS (70%) did not improve significantly. Sensitivity to detect tricuspid regurgitation was 33% but was assessed only with FCU. Specificity was ≥89% for all valvular diagnoses by both screening methods.

Importantly, the majority of clinically relevant cases of MR and AR were undetected with the stethoscope. In total, 28 (67%) cases of MR, 13 (62%) of AR, and seven (26%) of AS were missed. By contrast, only one (5%) clinically relevant case of MR and no cases of MR or AS were completely undetected with FCU (\( P < .001 \)). However, 13 (31%) cases of MR, 11 (52%) of AR, and eight (30%) of AS were underestimated as being mild with FCU, hence “clinically insignificant” in the accuracy calculations in which moderate or greater was used as a cutoff.

For nonvalvular diagnoses (with FCU as the only method), sensitivity to detect moderate or greater left ventricular (LV) dysfunction (90%) was excellent and detection of right ventricular dysfunction (79%) was good, while detection of dilated left atrium (53%), dilated right atrium (49%), pericardial effusion (40%), and dilated aortic root (25%) was less accurate. Specificity varied from 57% to 94%.

The predictive values confirm substantial accuracy for the detection of MR, AS, and LV dysfunction by FCU but also reveal poor positive predictive values for the detection of pericardial effusion and right ventricular dysfunction, which were hampered by a considerable number of false positives.

The level of agreement, expressed as Cohen’s \( k \), further reflects the above picture, with good agreement for the detection of AS, moderate agreement for the detection of MR and LV dysfunction, fair agreement for right ventricular dysfunction, pericardial effusion, and atrial dilation and slight agreement for aortic root dilation.\(^{20}\)

Table 2A shows the ranges of mean diagnostic scores among the 21 students. The mean value was 0.60 ± 0.21. Although the absolute values of this index are arbitrary, they serve to indicate a notable dispersion of the accuracy among the students.

Quality Assessment

Figure 3 shows the differences found in image quality among FCU recordings by students and standard echocardiograms by experts. A total of 22% of FCU examinations were of poor image quality, while 38% were good. In contrast, 92% of standard echocardiographic examinations were of good quality, while 8% were fair (\( P < .001 \)).

Table 4 presents diagnostic accuracy of expert interpretations from student-obtained FCU images. The overall sensitivity to detect significant cardiac lesions was significantly higher for experts than medical students (81% vs 59%, \( P < .001 \)). The superior accuracy of expert interpretations is further illustrated by Figure 2B, which compares the overall diagnostic scores for students and experts, calculated from our arbitrary scoring system. The overall expert score was significantly higher than the overall student score (0.76 vs 0.60, \( P < .001 \)).

Figure 4 illustrates some of the key findings, such as the underestimation of clinically relevant valvular lesions, and provides
The present study suggests that medical students, after only 4 hours of group training, could use FCU as a bedside tool to improve the accuracy of the physical examination. Detection of LV dysfunction was highly sensitive, and the overall assessment of valvular function was more accurate than by stethoscope. However, our results also indicate that the added value of FCU as a screening tool to detect clinically relevant valvular lesions was limited at this level of experience (Figure 1). There was a small difference in the number of patients identified with FCU compared with physical examination.

Some of the findings may be explained by characteristics of the study group. We note that clinically relevant aortic valve pathology was relatively uncommon, which may explain why no improvement in accuracy was found. On the other hand, MR and LV dysfunction were present in approximately 50%, making the probability of finding a difference more likely. In addition, the distribution of AS was different than the distributions of MR and AR in that the vast majority of cases of AS were severe. Only three cases were mild or moderate. The murmurs in most patients with AS were probably prominent and hence easy to identify with the stethoscope. Accordingly, the incremental value of FCU was smaller. Finally, although “innocent” systolic flow murmurs are quite common in the general population and could possibly affect the specificity of auscultation, the high prevalence of valvular pathology in our study group may explain why specificity remained high.
The observed underestimation of valvular diseases with FCU indicates a poor discrimination between negligible and clinically relevant valvular lesions. The fact that expert interpretations of students’ FCU studies were of superior accuracy suggest that even though suboptimal image acquisition impeded the students’ accuracy, their interpretive abilities were, as expected, also at an inferior level. It has previously been shown that both skills improve substantially after only a few weeks of training. Although diagnostic accuracy for aortic valve pathology was not improved, it is likely that additional training would have resulted in similar improvement.

Our findings are consistent with previous studies, which despite various training durations and different scanners, demonstrated that FCU might provide information even in the hands of inexperienced users.

Alexander et al. showed that 20 medical house staff with only 3 hours of FCU training could assess LV function and pericardial effusion with moderate accuracy, whereas assessment of valvular disease was less accurate. Martin et al. reported similar results in a selection of 10 hospitalists with five training scans. In a study by Croft et al. with nine internal medicine residents and in another study by Lucas et al. with eight hospitalists, the training time was increased to approximately 30 hours, including 15 hours of hands-on practice. The resulting diagnostic accuracy was excellent for the detection of LV dysfunction, pericardial effusion, and valvular disease. No self-study component was mentioned in these four studies.

Also, a number of studies from Spencer and colleagues have investigated the usefulness of FCU in various settings. One study by Decara et al. is of particular relevance to our study, as it demonstrated that 10 fourth-year medical students receiving 10 days of individualized instruction significantly improved their bedside diagnosis compared with physical examination alone. In this study, the accuracy for detection of valvular abnormalities was greater than for LV dysfunction.

Few studies have thus far investigated the use of the newly developed pocket-sized FCU devices by medical students. One was performed by Filipiak-Strzecka et al., in which two medical students were trained for a total of 25 hours, including 40 training scans. Assessment for LV function and pericardial effusion was very good, and assessment for mitral and aortic valve pathology was good. A learning-curve effect was noted. In another study by Panoulas et al., a total of five medical students and three junior doctors were trained for only 2 hours, including hands-on practice on 10 cases.

Diagnostic accuracy was greatly improved by adding bedside FCU after history, physical examination, and electrocardiography.

Altogether, our study was among those with the shortest duration of supervised training and the smallest number of training scans. Still, the results were comparable with those of most of the studies reported above. However, the online precourse component and the prolonged examination duration may have been compensating factors for the limited training time.

The discussion regarding FCU training requirements remains controversial. The European Association of Cardiovascular Imaging stated in a position paper that FCU training should be mandatory, without specifying details. The American Society of Echocardiography (ASE) recently published new recommendations regarding FCU. Although no specific training requirement could be provided because of the heterogeneity of former studies, it was noted that an “acceptable” level of skill might be obtainable with 20 to 30 studies if the scope of acquisition and interpretation were limited. Moreover, three basic components—didactic education, hands-on practice in image acquisition, and image interpretation experience—were proposed. From these recommendations, it is clear that the training program applied in our study was insufficient, but we note that all three core components were covered.

Along with the increasing availability of pocket-sized scanners, the question arises whether echocardiographic training should start during medical school. One-on-one proctored hands-on training is beyond doubt the best way to acquire such skills, but the possible demand for mass education of entire medical school classes necessitates novel educational concepts to be developed. In this context, our results may indicate that an online self-study component followed by hands-on training in a group could be a feasible teaching model, even though the extent proved to be undersized in the present study.

Various online courses have already been developed, such as the e-learning platform for pocket-sized ultrasound of the European Association of Cardiovascular Imaging, along with a number of commercially available courses. However, such platforms need scientific validation, and the significance of sufficient hands-on training must still be emphasized.

Interestingly, several medical schools have implemented integrated ultrasound curricula across all years of medical school, in which online courses and video podcasts are customized to complement the hands-on teaching sessions. For instance, students attending a 4-week emergency medicine ultrasound elective are expected to complete ≥150 studies with ≥25 in each of the following areas: focused assessment with sonography in trauma, cardiac, aorta, gallbladder, kidney, and obstetrics and gynecology. The initial experiences indicated that ultrasound is a valuable teaching tool across all years of medical school.

When implementing FCU among inexperienced users, the limited scope of practice must remain absolutely clear for the individual performing FCU. As stated in the latest FCU recommendations from the ASE, this method is meant to enhance bedside examinations, and it is not equivalent to a diagnostic echocardiographic study. This needs to be communicated to both patients and other health care professionals. Moreover, the potential impact of failure to refer patients for complete echocardiographic evaluation, because of false-negative results on an FCU examination, needs to be considered. As long as the operator is aware of these matters, FCU would hardly cause any adverse patient outcome. On the contrary, it could be used to detect unsuspected or asymptomatic disease. If not detected, the patient is not worse off for not having had the examination. If a false positive were reported, the negative consequences
would be mitigated by the imperative that all positive findings would be confirmed with standard echocardiography. However, as stated by the ASE, the implications of following up on abnormalities detected by the routine use of FCU at the time of physical examination, many of which would be false positives, also need to be considered.24

Limitations
The mean FCU duration of 17 minutes is a major limitation and seems very long and inappropriate in a clinical setting. FCU is undoubtedly not feasible if significant extra time would be added to the physical examination. Nevertheless, in this study, the main focus for the students was to obtain all images according to the protocol, rather than completing the examination as quickly as possible. Therefore, a time limitation was not applied. The small number of training scans may also partially explain the prolonged acquisition time. Future studies could shorten this duration significantly, for instance, by omitting imaging windows and targets of analysis and by increasing training time, to establish a clinically useful protocol.

We did not collect exact data to scientifically determine the value, extent, or variability of the self-study module before the course. Most

Table 4 Expert interpretations of the FCU recordings

<table>
<thead>
<tr>
<th>Cardiac pathology</th>
<th>SE Pos (total [n])</th>
<th>FCU Pos (n)</th>
<th>Sensitivity (%) (95% CI)</th>
<th>Specificity (%) (95% CI)</th>
<th>PPV (%) (95% CI)</th>
<th>NPV (%) (95% CI)</th>
<th>( \kappa )</th>
</tr>
</thead>
<tbody>
<tr>
<td>At least moderate MR</td>
<td>43 (102)</td>
<td>43</td>
<td>81 (66–91)</td>
<td>86 (74–94)</td>
<td>81 (66–91)</td>
<td>86 (74–94)</td>
<td>0.68</td>
</tr>
<tr>
<td>At least mild MR</td>
<td>84 (102)</td>
<td>83</td>
<td>95 (88–98)</td>
<td>83 (58–96)</td>
<td>96 (89–99)</td>
<td>79 (54–93)</td>
<td>0.77</td>
</tr>
<tr>
<td>At least moderate AR</td>
<td>22 (97)</td>
<td>17</td>
<td>68 (45–85)</td>
<td>97 (89–100)</td>
<td>88 (62–98)</td>
<td>91 (82–96)</td>
<td>0.71</td>
</tr>
<tr>
<td>At least mild AR</td>
<td>52 (97)</td>
<td>46</td>
<td>83 (69–91)</td>
<td>93 (81–98)</td>
<td>93 (81–98)</td>
<td>82 (69–91)</td>
<td>0.75</td>
</tr>
<tr>
<td>At least mild AS</td>
<td>29 (99)</td>
<td>33</td>
<td>97 (80–100)</td>
<td>93 (83–97)</td>
<td>85 (67–94)</td>
<td>98 (91–100)</td>
<td>0.86</td>
</tr>
<tr>
<td>At least moderate TR</td>
<td>14 (58)</td>
<td>19</td>
<td>86 (56–97)</td>
<td>84 (69–93)</td>
<td>63 (39–83)</td>
<td>95 (81–99)</td>
<td>0.62</td>
</tr>
<tr>
<td>At least mild TR</td>
<td>49 (58)</td>
<td>46</td>
<td>94 (82–98)</td>
<td>100 (63–100)</td>
<td>100 (90–100)</td>
<td>75 (43–93)</td>
<td>0.83</td>
</tr>
<tr>
<td>LV dysfunction*</td>
<td>59 (101)</td>
<td>68</td>
<td>92 (81–97)</td>
<td>67 (50–80)</td>
<td>79 (68–88)</td>
<td>85 (67–94)</td>
<td>0.60</td>
</tr>
<tr>
<td>RV dysfunction*</td>
<td>18 (82)</td>
<td>25</td>
<td>78 (52–93)</td>
<td>83 (71–91)</td>
<td>56 (35–75)</td>
<td>93 (82–98)</td>
<td>0.53</td>
</tr>
<tr>
<td>Pericardial effusion*</td>
<td>12 (104)</td>
<td>13</td>
<td>58 (29–84)</td>
<td>93 (86–97)</td>
<td>54 (26–80)</td>
<td>95 (87–98)</td>
<td>0.50</td>
</tr>
<tr>
<td>Left atrial dilation</td>
<td>90 (106)</td>
<td>78</td>
<td>84 (75–91)</td>
<td>88 (60–98)</td>
<td>97 (90–100)</td>
<td>50 (31–69)</td>
<td>0.55</td>
</tr>
<tr>
<td>Right atrial dilation</td>
<td>43 (85)</td>
<td>38</td>
<td>67 (51–80)</td>
<td>79 (63–89)</td>
<td>76 (59–88)</td>
<td>70 (55–82)</td>
<td>0.46</td>
</tr>
<tr>
<td>Aortic root dilation</td>
<td>38 (97)</td>
<td>40</td>
<td>74 (57–86)</td>
<td>80 (67–89)</td>
<td>70 (53–83)</td>
<td>82 (70–91)</td>
<td>0.53</td>
</tr>
<tr>
<td>Overall*</td>
<td>368 (931)</td>
<td>374</td>
<td>81 (77–85)</td>
<td>87 (83–89)</td>
<td>80 (75–84)</td>
<td>87 (84–90)</td>
<td>0.67</td>
</tr>
</tbody>
</table>

CI, Confidence interval; NPV, negative predictive value; Pos, positive/abnormal findings; PPV, positive predictive value; RV, right ventricular; SE, standard echocardiography.

*Moderate or greater pathology.

Figure 4 Image quality from a pocket-sized ultrasound system (top) compared with a high-end system (bottom). (A) Echogenic patient. (B) Moderate MR graded as mild by student. (C) Moderate AR graded as mild by student. (D) Aortic sclerosis.
students, however, reported 1 to 3 hours of learning. In addition, no posttest component was involved in this module, although this is advised in the latest FCU recommendations of the ASE.24

The study population was recruited from a tertiary hospital, where patients have a high prevalence of cardiac disease. This was suitable for the purpose of our study but limits the generalizability of our results.

In the physical examination protocol, identification of the apex impulse and palpation of the precordium were not included. Consequently, assessment for systolic LV dysfunction was performed only by FCU examination, not by physical examination.

The reference method for this study was the review reports from standard echocardiography performed and reviewed by different cardiologists, and a certain degree of interrater variability must be anticipated. FCU examinations were intended to take place with as short as possible an interval to standard echocardiography, to avoid hemodynamic alterations between examinations.

CONCLUSIONS

After brief group training, FCU with a pocket-sized scanner allowed a selection of medical students to detect clinically relevant MR significantly better compared with physical examination. However, the detection of AR and AS suffered from considerable underestimation of severity and accordingly did not improve significantly. LV dysfunction was also detected with high sensitivity. Although the group model educated a large number of students in an effective manner, the small number of training scans per student limited performance and prolonged acquisition times. Therefore, more extensive training is advised.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.echo.2014.08.001.

REFERENCES

