SPECIAL ARTICLE

Value of Interactive Scanning for Improving the Outcome of New-Learners in Transcontinental Tele-Echocardiography (VISION-in-Tele-Echo) Study

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Background: Point-of-care (POC) echocardiography may be helpful for mass triage, but such a strategy requires adequately trained sonographers at the remote site. The aim of this study was to test the feasibility of using a novel POC echocardiography training program for improving physicians' imaging skills during preanesthetic cardiac evaluations performed in a community camp organized for treating cataract blindness.

Methods: Seventeen physicians were provided 6 hours of training in the use of POC echocardiography; nine were taught on site and eight were taught online through a transcontinental tele-echocardiography system. The trained physicians subsequently scanned elderly patients undergoing cataract surgery. The quality of images was graded, and agreement between local physicians' interpretations and Web-based interpretations by worldwide experts was compared.

Results: A total of 968 studies were performed, with 660 used for validating physicians' competence. Major cardiac abnormalities were seen in 136 patients (14.2%), with 32 (3.3%) deemed prohibitive to surgery in unmonitored settings. Although good-quality images were obtained more frequently by physicians trained on site rather than online ($P = .03$), there were no differences between the two groups in agreement with expert interpretations. The majority of physicians (70.6%) expressed satisfaction with the training (average Likert-type scale score, 4.24 of 5), with no difference seen between the two groups. The training resulted in significant improvements in self-perceived competence in all components of POC echocardiography ($P < .001$ for all).

Conclusions: This study establishes the feasibility of using short-duration, one-on-one, personalized transcontinental tele-echocardiography education for wider dissemination of echocardiographic skills to local physicians in remote communities, essential for optimizing global cardiovascular health. (J Am Soc Echocardiogr 2015;28:75-87.)

Keywords: Focused ultrasound, Tele-echocardiography, Tele-education

Although physical assessment is an integral component of clinical evaluation, accurate clinical detection of structural heart diseases requires expertise and is difficult to standardize. Previous studies have demonstrated that the addition of an appropriate echocardiographic examination to the clinical assessment significantly increases diagnostic accuracy, reduces unwarranted diagnostic and treatment referrals, and facilitates the optimal utilization of health care resources.[1-3] These observations have gained further impetus with recent advances in technology that have allowed the miniaturization of echocardiographic equipment, rendering echocardiography suitable for use as a point-of-care (POC) modality.

Echocardiography, however, requires expertise, for both image acquisition and interpretation, which limits its wider use in community settings. Our previous humanitarian project (the American Society of Echocardiography: Remote Echocardiography With Web-Based Assessments for Referrals at a Distance [ASE-REWARD] study) involved highly trained sonographers, and the data stored in the project revealed that Web-based integration of POC imaging with remote, expert interpretation of stored images could successfully extend high-level echocardiographic expertise to remote communities.[4] However, the local availability of necessary expertise for image acquisition

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For a detailed list of the VISION-in-Tele-Echo Study investigators, please refer to Appendix 1.

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Abbreviations

ASE-REWARD = American Society of Echocardiography: Remote Echocardiography With Web-Based Assessments for Referrals at a Distance

CHD = Congenital heart disease

ExpS = Expert sonographer

LV = Left ventricular

PhyS = Physician sonographer

POC = Point-of-care

remained a challenge. Therefore, our second successive humanitarian mission had two objectives: (1) to test the feasibility of a Web-based training module for personalized remote ultrasound training in which physician trainees learn from remote educators by transmitting their handheld ultrasound images in real time during scanning sessions and (2) to compare the Web-based trained physicians with a group of physicians trained on site for overall proficiency in echocardiographic scanning and interpretation of studies performed in community settings. A cohort of elderly patients undergoing eye surgery in a mass community eye surgery camp was used to answer these research questions because of the known associations between cataracts and cardiovascular diseases.[5,6] The quality of imaging and the overall accuracy of interpretations were validated by remote Web-based interpretation of stored images by worldwide echocardiography experts.

METHODS

The project was conducted in two phases: initial training of physician sonographers (PhyS) and subsequent physician-driven echocardiographic evaluation during preanesthetic assessment in a community eye surgery camp (Figure 1).

Recruitment and Training of PhyS

Volunteer physicians without formal echocardiographic training but with varying previous experience in echocardiography were invited, through e-mail communications, to participate in the study. Seventeen PhyS (median age, 38.5 years; interquartile range, 36.3–43.5 years), who had obtained postgraduate qualification in various medical specialties (12 with diplomas in clinical cardiology and one each in internal medicine, psychiatry, anesthesia, maternal and child health, and anatomy) were ultimately recruited. The diploma in clinical cardiology is a 2-year training program available after medical school graduation, without any need to undergo prior residency in any medical specialty. The primary intent of this program is to train community physicians in providing appropriate clinical care to patients presenting with various cardiac illnesses in remote communities in India, where the burden of cardiovascular diseases has reached epidemic proportions.[7,8] The median time interval since participants' last medical qualification was 6 months (interquartile range, 6 months to 1.6 years).

Although none of these 17 PhyS had undertaken echocardiography fellowships or received formal structured training in echocardiography, they reported variable degrees of exposure to echocardiography previously. Six physicians reported previous experience of <6 months (with four having no experience at all), and five reported 6 months to 1 year of performing echocardiography without formal supervision. However, this experience did not represent regular time spent in an echocardiography laboratory performing scanning or interpreting studies on a regular basis but only "intermittently observing/performing" echocardiography when feasible during their regular clinical duties. Thus, their levels of expertise in echocardiography did not fulfill level 1 training criteria per the 2008 recommendations for training in adult cardiovascular medicine of Core Cardiology Training Symposium 3.[9] The remaining six physicians had been performing echocardiography for durations that could meet Core Cardiology Training Symposium 3 level 1 criteria, but in the absence of formal, structured training in echocardiography, their overall competence in echocardiography remained nonuniform.

After recruitment in the project, the PhyS were provided 6 hours of focused training, at a tertiary care collaborating center in north India, in the performance of POC echocardiography by expert sonographer (ExpS) volunteers, who were American Society of Echocardiography (ASE) members with previous experience in teaching. Five ExpS traveled to India for onsite training of nine PhyS, whereas the remaining eight sonographers trained eight PhyS remotely through a Web-based tele-echocardiography system.

The training began with a 1-hour lecture that introduced the fundamentals of basic echocardiographic examination and oriented the participants to the specifically designed scanning protocol, consisting of 11 standard views, including color-flow Doppler images of all valves (Appendix 2). This was followed by hands-on training using the pocket-size and handheld cardiac ultrasound units (Vscan and Vivid I and Vivid Q portable cardiac ultrasound systems, respectively; GE Medical Systems, Milwaukee, WI). The Vscan is a small, pocket-size device (135 × 73 × 28 mm), weighs <400 g, and has an 8.9-cm (diagonal) display with a resolution of 240 × 320 pixels. It uses a phased-array transducer (1.7–3.8 MHz) and displays grayscale images with a sector width of 75° and color Doppler with a fixed sector width of 30° and does not have the capabilities of spectral Doppler and M-mode imaging. The Vivid I and Vivid Q are laptop-based portable systems that allow more comprehensive examinations.

Remote Web-Based Training. Of the 17 PhyS, eight were trained remotely through a Web-based tele-echocardiography system. The live tele-echocardiography training was accomplished using Vivid I and Vivid Q systems connected to the internet via EchoBox (StatVideo LLC, Andover, MA) devices that allowed live streaming of echocardiographic images to designated Web portals. These images were accessed in real time by the ExpS in the United States, who simultaneously used a standard internet messaging application to communicate with the scanning physicians in India. Through these communication channels, the ExpS guided the scanning physicians through the whole process of image acquisition (machine settings, transducer position, etc) to image interpretation.

There was no difference in the level of expertise between the ExpS who were available on site and those who were involved in the remote training. In addition, both forms of training involved exposure to a similar spectrum of cardiac pathologies commonly encountered in clinical practice, such as various forms of valvular heart diseases, ischemic and nonischemic left ventricular (LV) systolic dysfunction, hypertensive heart disease, and so on. However, congenital heart disease (CHD) could not be represented, even though it was not purposely excluded.

Mass Echocardiographic Scanning in the Community Camp

The second phase of the study was conducted at a community eye surgery camp that is held annually in a spiritual organization in a rural location in north India. Although this was the location of our previous

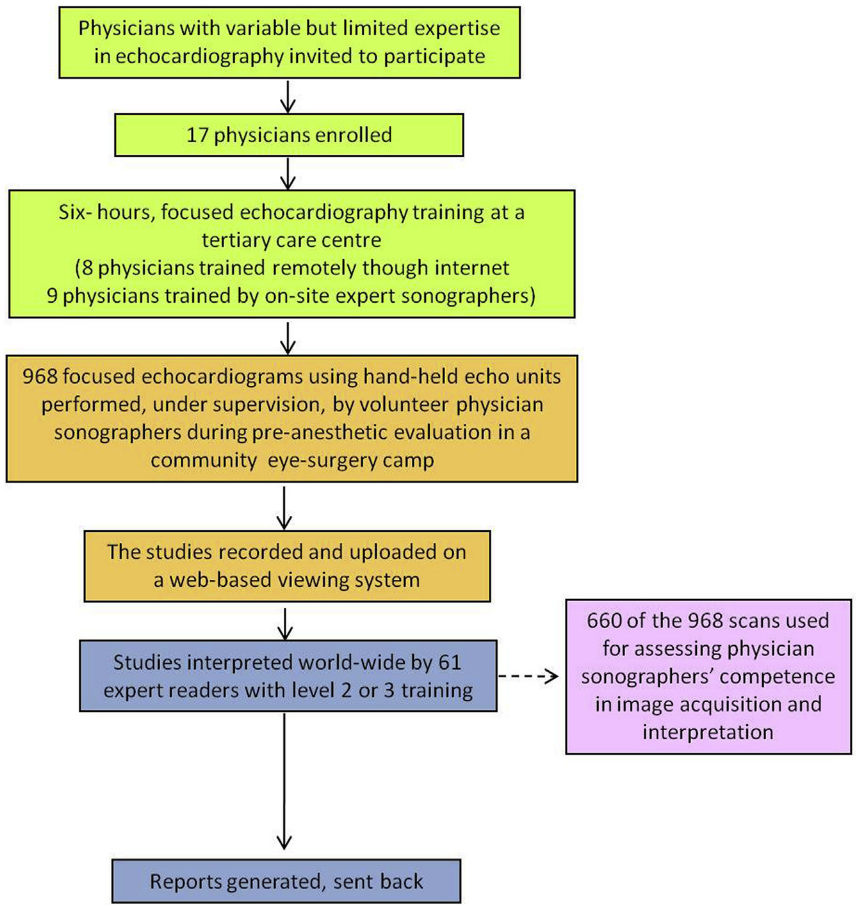

Figure 1 Project workflow.

ASE-REWARD study as well,[4] the two studies were conducted 11 months apart and included entirely different patient populations.

All patients who had been clinically examined by the surgical team and were deemed free of significant cardiac disease and fit to undergo surgery were included in the study and subjected to echocardiographic screening during the preanesthetic evaluation. Patients with known cardiovascular illnesses had already been excluded to avoid any unwarranted cardiac complications during the surgery performed in the camp.

Echocardiographic Examination, Image Transfer, and Interpretation. The scanning was performed by the PhyS under supervision of the ExpS, who ensured completion of the studies and also provided back-up support in the event of PhyS fatigue. The backup support was available to all PhyS, irrespective of mode of training and previous experience in echocardiography.

The studies were initially performed on Vscan, and whenever a major cardiac abnormality was identified that required better delineation, scanning was repeated on Vivid I and Vivid Q systems. All studies were digitally recorded in either a Motion Picture Experts Group layer 3 or Digital Imaging and Communications in Medicine format. Upon completion of each study, the PhyS generated a provisional echocardiographic report using a standardized template, which included information about chamber dimensions, valve morphology, color-flow Doppler, global and regional LV systolic function, and any apparent congenital cardiac malformations. Any other abnormality, if found, was also recorded. All studies were also uploaded to a cloud-based Web server (Studycast, Raleigh, NC), using commercially available software (CoreConnect; Core Sound Imaging, Raleigh, NC) that captured the study images from the ultrasound units and transmitted them to the image and workflow management component (CoreWeb; Core Sound Imaging). Worldwide interpretations of these uploaded studies were performed by 61 volunteer physicians with level 2 or 3 or equivalent training who had preregistered with the ASE. The reports were finalized on the Web-based system, using the same template used by the PhyS, with the goal of accomplishing this within 24 hours of initial scanning. The reports were subsequently downloaded and printed by the local coordinators, who distributed these reports to the patients. The remote readers were blinded to the interpretation made by the onsite readers.

For the purposes of analysis and interpretation, readers were requested to give only visual, qualitative assessments (mild, moderate, or severe) on specific pathologic issues: LV dilation, LV wall hypertrophy (concentric or asymmetric), reduction of LV function (visual ejection fraction), segmental wall motion abnormality (yes or no), right ventricular dilation, left atrial dilatation, aortic root dilatation, valve calcification, pericardial effusion, pleural effusion, and dilation with reduced inspiratory reactivity of inferior vena cava. LV ejection fraction was considered low if it was <55% by visual estimation and graded by ASE-recommended definitions for LV dysfunction as mild (45%–54%), moderate (30%–44%), and severe (<30%).[10] The presence of valvular abnormalities (regurgitant or stenotic) and their grade (mild, moderate/severe) were also recorded. The severity of regurgitant lesions was based on two-dimensional findings (atrial or ventricular enlargement, hyperdynamic left ventricle) and qualitative color Doppler findings (width of vena contracta and jet area), whereas the severity of stenotic lesions was based on two-dimensional findings of valve opening and leaflet mobility, thickness, and calcification alongside chamber size changes (hypertrophy in aortic stenosis, atrial dilatation in mitral stenosis). An abnormality was considered major if any of the following was found: valvular regurgitation of moderate or greater severity, any valvular stenosis, all CHDs (except bicuspid aortic valves in the absence of any other associated significant abnormality), any LV systolic dysfunction or wall motion abnormality, and any other moderate or severe abnormality (e.g., moderate aortic root dilatation, moderate LV hypertrophy). All other echocardiographic abnormalities were deemed to be minor.

PhyS Survey about Their Experience

At the completion of the activity, the participating PhyS were administered a modified five-point, Likert-type scale questionnaire (1 = "completely dissatisfied/unconfident," 3 = "neutral," 5 = "completely satisfied/confident") to collect information about their overall experience during the activity and the improvement, if any, in their self-perceived competence in difference components of using POC echocardiography (Appendix 3).

Both the hospital and the state governmental authorities provided approval for this humanitarian and educational event. All patients consented to the preoperative workup (including echocardiography) and to undergo cataract surgery. All physicians and experts agreed to participate, including in the survey analysis. The hospital and local ethics committee provided approval for carrying out retrospective analysis of the stored information for research.

Data Analysis and Interpretation

All data were managed and analyzed using a Microsoft Excel 2007 spreadsheet (Microsoft Corporation, Redmond, WA). Continuous data are reported as the mean ± SD (or median and interquartile range, if not normally distributed), and categorical data are reported as numbers and percentages. Chi-square test was used to analyze differences in the categorical variables between the two training groups. Cohen's κ was calculated as a measure of agreement between the onsite and remote expert interpretations. The responses to survey questions were analyzed using Mann-Whitney test or Wilcoxon signed rank test as appropriate. A P value $<.05$ was considered statistically significant.

RESULTS

A total of 968 echocardiographic studies were performed during the entire activity. The mean age of the subjects was 57.9 ± 13.3 years, and 492 (50.8%) were men.

Overall Image Size, Data Flow, and Image Quality

On average, each study consisted of 19 ± 6 clips with an average size of 5.4 ± 2.7 MB. The median time delay from scanning to image upload was 8.35 hours (interquartile range, 4.51–21.24 hours) and from scanning to final interpretation was 10.65 hours (interquartile range, 3.92–24.47 hours).

Of the 968 scans, 861 (88.9%) were graded to have excellent, good, or fair image quality and another 46 (4.8%) as technically difficult but adequate. The remaining 61 (6.3%) had poor or limited image quality, but only 12 (1.2%) were nondiagnostic, precluding any meaningful interpretation. Importantly, there was no difference in the overall image quality across different skill levels (89.4%, 87.9%, and 85.3% of scans with fair to excellent image quality with PhyS with <6 months, 6 months to 1 year, and >1 year of previous experience in echocardiography; $P = .41$).

Table 1 Major echocardiographic abnormalities in the study patients (n = 136)*

Echocardiographic abnormality	Patients
Significant LV systolic dysfunction	64 (47.1%)
Regional	34 (25.0%)
Global	30 (22.1%)
Significant valvular heart disease	51 (37.5%)
Mixed valve disease and LV systolic dysfunction	13 (9.6%)
CHD†	10 (7.4%)
Atrial septal defect	6 (4.4%)
Ventricular septal defect	4 (2.9%)
LV hypertrophy	10 (7.4%)
Concentric	8 (5.9%)
Asymmetric	2 (1.5%)
Other abnormalities	22 (16.2%)
Left atrial enlargement	13 (9.6%)
Right ventricular dilatation with or without dysfunction	4 (2.9%)
Aortic root dilatation‡	2 (1.5%)
Intra- or extracardiac mass	2 (1.5%)
Abnormal septal motion suggesting constrictive pericarditis	1 (0.7%)

*Patients were assigned to particular diagnostic categories on the basis of the most dominant abnormalities found. When a patient had more than one severe abnormality, he or she was placed in all relevant categories.
†Ten more patients had questionable evidence of CHD.
‡One patient had suspected aortic dissection.

Echocardiographic Findings

Of the 956 (98.8%) scans that could be interpreted, 569 (59.5%) were found to be normal, 251 (26.3%) had minor abnormalities, and 136 (14.2%) had major abnormalities (Table 1, Figures 2 and 3).

LV systolic dysfunction was the most common major cardiac abnormality, reported in 64 subjects (47.1% of those with major abnormalities), and was moderate to severe (LV ejection fraction < 45%) in 30 patients (Video 1; available at www.onlinejase.com). More than half of these patients (n = 34 [53.1%]) had regional wall motion abnormalities, whereas the remaining had global LV systolic dysfunction.

Valvular heart disease was the second most common abnormality, with 51 patients (37.5% of those with major abnormalities) having significant valvular heart disease (Tables 1 and 2) and another 156 patients (16.3%) having mild valvular heart disease (Videos 2a, 2b, 3a, and 3b; available at www.onlinejase.com). Regurgitant lesions were more common than stenotic lesions, and the mitral valve was the most commonly involved valve. A wide array of other cardiac abnormalities, such as LV hypertrophy, left atrial dilatation, aortic root dilatation (with suspected aortic dissection in one patient; Video 4; available at www.onlinejase.com), right

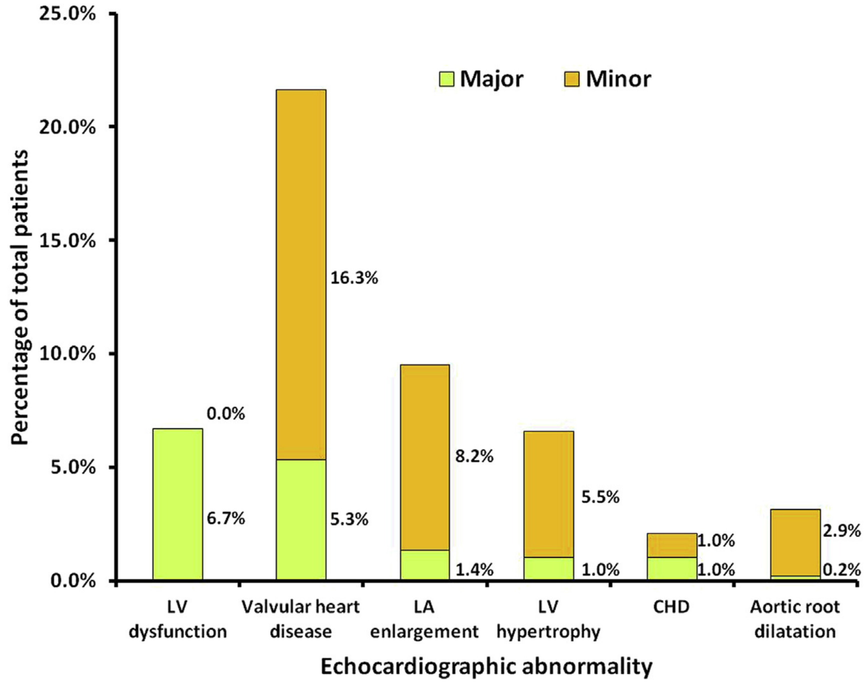

Figure 2 Distribution of the overall minor and major echocardiographic findings in the study subjects. *LA*, Left atrial.

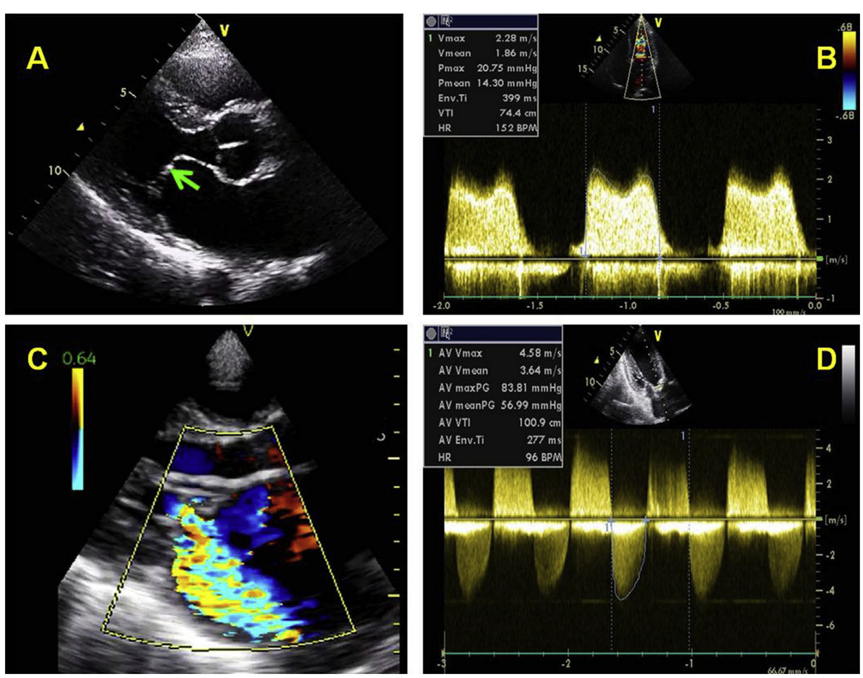

Figure 3 Illustrative examples of major cardiac lesions diagnosed by POC echocardiography in the camp. **(A)** Rheumatic heart disease with thickened mitral valve leaflets and doming of anterior mitral leaflet (arrow) resulting in significant mitral stenosis. **(B)** Markedly increased transmitral gradients consistent with severe mitral stenosis. **(C)** Another patient with rheumatic heart disease with posteriorly directed, eccentric severe mitral regurgitation. **(D)** Continuous-wave spectral Doppler across aortic valve showing significantly elevated transaortic gradients in a patient with severe aortic stenosis.

heart enlargement, and so on, were also seen, but most often these abnormalities were only mild. In addition, 10 patients (1.0% of the total and 7.4% of those with major echocardiographic abnormalities) were found to have CHD (six with small atrial septal defects, four with small ventricular septal defects).

Significant Echocardiographic Abnormalities with Potential Surgical Implications. Of the patients with major echocardiographic abnormalities, 32 (3.3% of the entire study population) had pathologies (severe LV systolic dysfunction in 15 patients, significant valve lesions [severe valvular regurgitation and/or moderate to severe

Table 2 Significant valvular heart disease in the study patients (n = 51)*

Valvular heart disease	Patients
Significant mitral valve disease	29 (56.9%)
Stenosis	7 (13.7%)
Regurgitation	16 (31.4%)
Both	6 (11.8%)
Significant aortic valve disease	24 (47.1%)
Stenosis	8 (15.7%)
Regurgitation	14 (27.5%)
Both	2 (3.9%)
Significant tricuspid valve disease	9 (17.6%)
Regurgitation	9 (17.6%)
Mixed valvular heart disease	12 (23.5%)

*Patients were assigned to particular diagnostic categories on the basis of the most dominant abnormalities found. When a patient had more than one severe abnormality, he/she was placed in all relevant categories.

valvular stenosis] in 13, severe right heart enlargement in two, suspected aortic dissection in one, and hypertrophic obstructive cardiomyopathy in one) deemed prohibitive to cataract surgery in an unmonitored setting (Figure 3, Videos 1, 2a, 2b, 3a, 3b, and 4). As a result, their surgeries were rescheduled to be performed later in a hospital under cardiac monitoring.

Effect of Training Mode on Imaging Outcomes

A total of 192 scans were performed by ExpS during the training sessions. Of the remaining 776 scans, 116 scans had to be excluded because the copies of the provisional echocardiography reports retained for later analysis were not readable. The remaining 660 scans (346 by onsite-trained PhyS, 314 by remotely trained PhyS) were available for assessing the impact of training mode on imaging outcomes. A comparison of onsite and remote interpretations revealed that the PhyS could recognize major echocardiographic abnormalities with 58.7% sensitivity and 97.0% specificity (overall $\kappa = 0.62$, $P < .001$), though severity was underestimated by one grade in 11 studies (11.2%) and overestimated in another 11 (2.0%). Diagnostic accuracy was the best for valve lesions (sensitivity, 80.9%; specificity, 99.8%; $\kappa = 0.88$; $P < .001$) and relatively modest for LV systolic dysfunction (sensitivity, 58.0%; specificity, 98.3%; $\kappa = 0.62$; $P < .001$) (Table 3, Figure 4). Most of the observed differences between onsite and expert interpretations were related to localized LV wall motion abnormalities (hypokinesia or akinesia of one or two segments) and/or mild LV systolic dysfunction, CHDs (small atrial and ventricular septal defects), and chamber enlargements (left atrial, aortic root, or right ventricular dilatation or LV hypertrophy).

There was no statistically significant difference in the overall baseline imaging experience of the two groups ($P = .48$), though the onsite-trained group included more PhyS who reported >1 year of personal time spent performing or observing echocardiography (Table 3). A comparison of the image quality and diagnostic accuracy achieved by the two groups revealed that although the remotely trained PhyS were able to obtain good-quality images in the vast majority of patients (84.4%), this was statistically inferior to those trained onsite (90.2%) ($P = .03$). However, there was no significant differences in the accuracy of findings reported by onsite versus remotely trained physicians (overall κ for major abnormalities = 0.62 for both, $P = .49$; Table 3).

PhyS Experience and Impact of Training

The majority of PhyS (12 of 17 [70.6%]) expressed complete or at least reasonable satisfaction with their overall experience during the entire activity (average score, 4.24 of 5). A similar experience was also shared by the remotely trained PhyS when assessed separately, with no difference in the overall satisfaction between the two groups ($P = .87$; Table 3). Seven of the remotely trained PhyS (87.5%) found Web-based training good enough to be a potential alternative to onsite training when an onsite trainer was not available. For both groups, the training resulted in significant improvements in self-perceived competence in all components of POC echocardiography ($P < .001$ for all; Figure 5).

DISCUSSION

To the best of our knowledge, this is the largest study to demonstrate that physicians with variable but limited experience in echocardiography can be rapidly trained to use POC echocardiography. In addition, the study also demonstrated the feasibility of imparting such training using a remote, Web-based tele-echocardiography system. The majority of physicians trained remotely found it to be a satisfactory mode of training, with image quality and study interpretation that were comparable with those of physicians trained onsite. Combining such training with Web-based integration of remote, expert interpretation of stored images could permit the delivery of high-level echocardiographic expertise to remote communities, which in this study was used for successful risk stratification of patients undergoing a surgical procedure in a community setting.

POC Echocardiography as an Adjunct to Clinical Examination

Numerous studies over the past decade have demonstrated that the addition of a screening echocardiographic examination to clinical assessment significantly increases diagnostic accuracy, reduces unwarranted diagnostic and treatment referrals, and facilitates the optimal utilization of health care resources.[1-3] For example, Mjolstad *et al.*[2] studied 196 patients admitted to the medical department at a tertiary care hospital and showed that the addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy. Similar findings were reported by Cardim *et al.*[1] in an outpatient setting, with POC imaging significantly improving diagnostic accuracy and reducing unnecessary echocardiography referrals.

The incremental value of echocardiography over physical examination in diagnosing cardiac diseases is likely to be even greater in community settings, where treating physicians may not have the desirable level of clinical skills and where high patient volumes, time constraints, and noisy surroundings further compromise their ability to accurately diagnose cardiac illnesses. In our study, 14.2% of patients who were clinically believed to be free of any major cardiac illness were indeed found to have significant cardiac diseases on echocardiography. This clearly demonstrates the high yield of POC echocardiography in identifying clinically unrecognized cardiac disorders in such difficult environments.

Training Requirements for POC Echocardiography

Echocardiography is a highly specialized diagnostic modality and requires adequate expertise in image acquisition and interpretation to ensure optimal diagnostic accuracy. Although the currently used miniaturized devices for POC echocardiography offer less

Table 3 Salient findings in the two groups by training methodology

Parameter	Onsite-trained physicians (*n* = 9)	Remotely trained physicians (*n* = 8)	*P*
Total scans performed	346	314	
Baseline echocardiographic experience of the scanning physicians			.48
<6 mo	2	4	
6 mo to 1 y	3	2	
>1 y	4	2	
Scans with fair to excellent image quality	312 (90.2%)	265 (84.4%)	.03
Echocardiographic findings			.30
Major abnormalities	43 (12.4%)	31 (9.9%)	
Minor abnormalities	77 (22.3%)	84 (26.8%)	
Diagnostic accuracy for major lesions			
Overall diagnosis			
Sensitivity (%)	59.1	58.1	
Specificity (%)	96.8	97.3	
κ	0.62	0.62	.32
LV systolic dysfunction			
Sensitivity (%)	59.4	55.6	
Specificity (%)	98.4	98.3	
κ	0.65	0.58	.56
Valvular heart disease			
Sensitivity (%)	81.5	80.0	
Specificity (%)	99.7	100.0	
κ	0.87	0.88	.65
Overall satisfaction with training quality*			
Average score ± SD	4.6 ± 0.5	3.9 ± 1.8	.87
Median	5.0	5.0	

*Scores were derived using a five-point modified Likert-type scale questionnaire (1 = "completely dissatisfied," 3 = "neutral," 5 = "completely satisfied").

complicated platforms to users, the technical expertise required for using them is not necessarily less extensive. Small screen size, suboptimal spatial and temporal resolution, limited capability to minimize artifacts, and the absence of spectral Doppler to provide corroborative information are some of the problems unique to these small devices that add to the challenges in image acquisition and interpretation.

The ASE recently released a consensus document outlining key elements involved in the performance of focused cardiac ultrasound.[11] Although focused cardiac ultrasound is a distinct entity from POC echocardiography, with the latter requiring considerably greater expertise, the fundamental principles defining the training requirements for the two are largely similar. It is therefore interesting to note that several of the recommendations proposed for focused cardiac ultrasound in the ASE consensus document were met in our study. The majority of the PhyS in our study had the necessary clinical background in internal medicine or cardiology, making it easier for them to rapidly grasp the fundamental concepts of echocardiography. In addition, the training was provided hands on, under the direct supervision of ExpS, and using the same ultrasound devices that were later used for scanning in the camps. Furthermore, the scanning during initial training was also performed on patients only, not volunteers. Perhaps these were some of the reasons why the PhyS in our study were able to gain reasonable echocardiographic competence within a short period of time. At the same time, however, their previous exposure in echocardiography, though largely limited, likely also made it easier for them to acquire the necessary skills to perform POC echocardiography. Nevertheless, the lack of a significant difference in overall image quality across different skill levels provides evidence supporting the feasibility of rapidly training community physicians in echocardiographic image acquisition. Most previous studies on the use of pocket-size or handheld echocardiographic equipment involving relatively inexperienced imagers have focused primarily on the diagnostic accuracy achieved and have not sufficiently elaborated the quality of the images obtained by such users.[12-17]

In our study, we also assessed the interpretive ability of the PhyS for common echocardiographic findings by using a Web-based strategy to remotely obtain expert interpretation of the images acquired in the community. Given the challenging circumstances of the community camp and the inherent limitations of handheld ultrasound devices, these PhyS were able to achieve a reasonable degree of diagnostic accuracy, particularly for the conditions (e.g., valvular heart disease) that were less ambiguous to diagnose by visual, qualitative assessment alone. Most of the abnormalities that were missed included small atrial or ventricular septal defects and chamber enlargements. This was not a surprising finding given that the PhyS were not trained in diagnosing CHD, and also because qualitative assessment of chamber enlargements is usually difficult and requires considerable expertise. Notably, the diagnostic accuracy achieved in our study was comparable with what was reported in a previous study involving echocardiographers with similar levels of baseline expertise.[16]

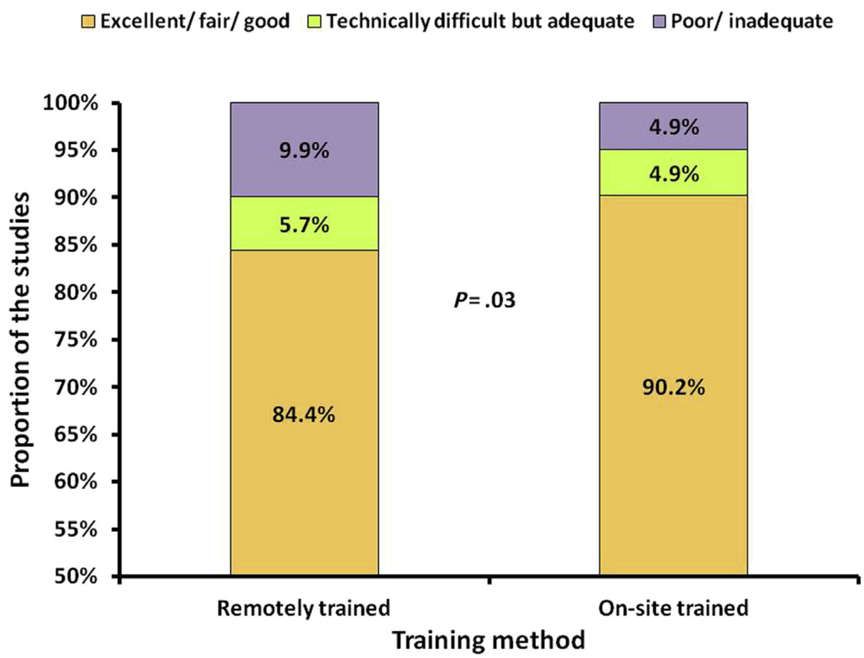

Figure 4 Image quality according to training method.

Remote Web-Based Training

Because high-level expertise in echocardiographic teaching is generally confined to larger centers only, the primary objective of the present study was to test the feasibility of a novel, Web-based, real-time, hands-on, personalized training program for remotely training physicians on the use of pocket-size and handheld ultrasound. The PhyS trained remotely through the internet had a high degree of satisfaction with the quality of training and were able to achieve similar imaging outcomes compared with the PhyS trained on site. The remote mentors, however, reported interference due to background noise, which occurred mainly because multiple training sessions were conducted simultaneously in the same room. Allowing only one user per room, using a head-mountable microphone instead of a table-mounted one, and better soundproofing of the examination room could easily mitigate this problem.

Although live streaming of echocardiographic images with real-time proctoring is being increasingly used to facilitate echocardiographic evaluation of patients at a distance,[18-22] remote Web-based echocardiographic training at such a large scale has never been attempted.

Community Eye Surgery Camp as the Clinical Setting for Using POC Echocardiography

Recent evidence suggests a worldwide shift in disease burden from communicable to noncommunicable diseases and the presence of diseases that cluster frequently in the aging population.[23] A crucial step, therefore, is to identify vulnerable populations in the community who are at the highest risk for experiencing adverse health events.

A few studies have suggested increasing cardiovascular mortality in patients with cataracts, suggesting that cataracts may be a biomarker of aging and associated with increased cardiovascular risk.[5,6] Intriguingly, lenticular changes reflect molecular, cellular, and epigenetic mechanisms, including long-standing oxidative stress and protein denaturation, that also participate in the development of cardiovascular diseases. The presence of cataracts may therefore identify a population at increased risk for cardiovascular events, and screening such a population may help further risk stratification and address the need for further health care services. Our finding that a sizable proportion of the patients undergoing cataract surgery were discovered to have major cardiac diseases, despite being clinically deemed free of any major cardiac illness, firmly supports these observations.

The community surgical camps represent a commonly used health care delivery model in countries such as India that face the dual burden of unusually high disease prevalence and socioeconomic barriers in accessing proper health care services. These camps use low-cost solutions to offer reasonably sophisticated surgical care at a mass level and are therefore able to extend the health care benefit to a large section of the underprivileged society. However, because of often inadequate preoperative workup and limited facilities for perioperative care, these camps also expose patients to the risk of unanticipated perioperative complications. In a previous study in which cataract surgery was performed at institutions with proper perioperative monitored settings, the incidence of adverse events was found to be 33 per 1,000 procedures.[24] This risk was likely to be higher in the present study as the surgeries were preformed without any cardiac monitoring. Therefore, the incremental value of POC echocardiography in this setting to allow safe delineation of patients who would benefit from close perioperative monitoring cannot be overemphasized. In our study, 3.5% of patients clinically considered to be acceptable for surgery were later found to have cardiac diseases severe enough to pose appreciable risk for perioperative cardiac complications. These procedures were rescheduled to be performed subsequently in a hospital under cardiac monitoring. This practice would be consistent with observations in a recent study in which the discovery of unstable cardiac and noncardiac conditions led to delays in the performance of eye surgery in 12% patients.[25] In addition, the detection of severe cardiac illness has relevance not only for ensuring patient safety by avoiding surgery in unmonitored settings but also for long-term patient health by prioritizing continuity of care in underprivileged communities.

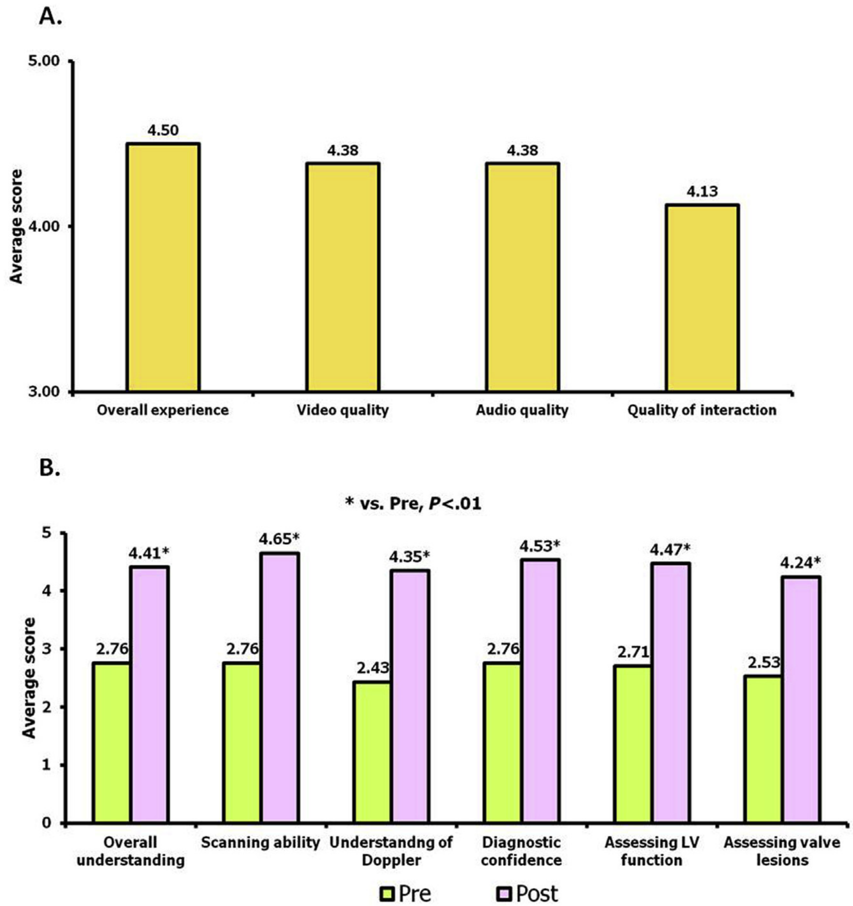

Figure 5 **(A)** Overall experience of PhyS with the remote, Web-based training. **(B)** Overall impact of training on the self-perceived competence of the physicians in different components of POC echocardiography. All scores were derived using a five-point modified Likert-type scale, as described in the text.

It is important to emphasize that the existing practice guidelines on preoperative cardiac evaluation of patients undergoing major noncardiac surgery do not recommend echocardiography as a routine procedure for all patients. Subjects who are physically active and able to perform ≥4 metabolic equivalents of activity without any symptoms do not require further testing for relatively low-risk surgery.[26] However, the generalizability of the existing guidelines and safety criteria is not well established for procedures performed in remote locations where standard monitoring facilities are unavailable and an adequate preoperative clinical assessment is either not feasible or relatively inaccurate for logistic reasons. Although this does not imply that routine echocardiography would be needed in all patients undergoing surgery in a community setting, it would be reasonable to speculate that the incorporation of echocardiography as a diagnostic modality may be useful for triaging patients in situations in which the prevalence of undiagnosed serious structural heart lesions is high. Although the primary intent of this study was to investigate a strategy of remote training in echocardiography, the cohort of elderly patients undergoing cataract surgery with an undiagnosed burden of cardiac diseases allowed us to investigate this hypothesis.

Limitations

Our study had several limitations that merit attention. First, for logistic reasons, we could not use elaborate, objective tools for quantifying the impact of training on different components of competence among PhyS in using POC echocardiography and to determine the influence of baseline skill and mode of training on the imaging outcomes. Instead, as a surrogate, we used a questionnaire to assess participating physicians' self-perceived competence, which had obvious inherent limitations. Although the comparison of the image quality and the overall diagnostic accuracy achieved by the two groups provided corroborative evidence to support the information derived from the questionnaire, further studies are required to specifically address each of these issues.

Second, although the initial intense training was only for 6 hours, subsequent echocardiographic scanning during the camp provided continued learning opportunity to the PhyS and must have contributed to further improvements in their imaging abilities. It thus partially blurred the distinction between onsite and Web-based training. However, it is noteworthy that both groups of PhyS performed the same number of studies (38 scans per PhyS in the onsite-trained group, 39 scans per PhyS in the remotely trained group) over 2 days, and only 31 studies performed by remotely trained PhyS were deemed to have poor image quality, as compared with 17 for those trained on site. These data suggest that not only did the remotely trained PhyS not take longer time to complete each scan, their learning curve was also not different from that of those trained on site.

Third, in the community camp, the PhyS performed echocardiographic scanning under supervision by ExpS, which precluded assessment of their ability to independently perform POC echocardiography. However, the purpose of the present study was never to propose that brief, intense echocardiographic training could serve as a substitute for the more detailed training required to achieve necessary expertise for independent image acquisition and interpretation. Rather, our aim in the present study was to show (and we did demonstrate) how local resources could be successfully engaged to amplify limited available high-level expertise in benefiting a much larger section of the underprivileged community. In our study, after the initial personalized training sessions, only five ExpS monitored the needs of 17 PhyS. This reflects a substantial reduction in the need for the availability of ExpS at the community level. Longer personalized training sessions may further reduce the need for ExpS on site. Even better, the use of new telemedicine and telepresence technologies may potentially eliminate the need for experts on site; however, this must be tested in future investigations.

Finally, as discussed in the ASE-REWARD study, the grading of echocardiographic abnormalities on the basis of visual, qualitative assessment alone has its own inherent limitations. It introduces an element of subjectivity and influences the diagnostic accuracy of the interpretation. Nevertheless, several previous studies have used a similar approach and have shown qualitative assessment to be an acceptable strategy with good to excellent diagnostic accuracy demonstrated for multiple echocardiographic abnormalities.[3,27,28]

CONCLUSIONS

This study demonstrates the potential feasibility of a strategy of high-intensity, Web-based, real-time, hands-on, personalized training program to educate local community physicians on the use of pocket-size and handheld ultrasound. Such training, combined with Web-based integration of remote, expert interpretation of stored images, allows the delivery of echocardiographic expertise to remote communities, which could be of great help in optimizing cardiovascular health outcomes in these communities.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.echo.2014.09.001.

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APPENDIX 1. COMPLETE LIST OF THE VISION-IN-TELE-ECHO STUDY COLLABORATORS

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APPENDIX 2. ECHOCARDIOGRAPHIC SCANNING PROTOCOL USED IN THE STUDY

- Voice-record patient's name and study number on the Vscan; verify on worksheet
- Views to be obtained

1.1. Parasternal long-axis view (PLAX): two-dimensional (2D)
1.2. PLAX: color (for assessing aortic and mitral regurgitation)
1.3. Parasternal short-axis view (PSAX) at aortic valve (AOV) level: 2D
1.4. PSAX at AOV level: color
1.5. PSAX at mitral valve (MV) level (visualize MV orifice)
1.6. PSAX at MV level: color
1.7. PSAX at papillary muscle level
1.8. Four-chamber: 2D (full visualization of atria and ventricles)
1.9. Four-chamber: color mitral regurgitation
1.10. Four-chamber: color tricuspid regurgitation
1.11. Five-chamber: color aortic regurgitation
1.12. Additional images in the event a lesion is profiled

Appendix 3 Questionnaire Used for Assessing Overall Experience and Satisfaction of PhyS during the Training Activity

No	Question	Your response
1	Before participating in this activity, how much was your experience in performing regular hands-on echocardiography- A. <6 months; B. 6 months- 1 yr; C. >1yr	
2	How satisfied you were with your overall experience during the entire activity? Rate on a scale of 1-5, 1- completely dissatisfied, 2- somewhat dissatisfied, 3- Neutral, 4- somewhat satisfied, 5- completely satisfied	
3	How would you rate your overall understanding of the concepts of echocardiography **prior to** participating in this activity? Rate on a scale of 1-5, 1- very basic, 2- somewhat basic, 3- reasonable, 4- good, 5- very good	
4	How would you rate your overall understanding of the concepts of echocardiography **at the end** of this activity? Rate on a scale of 1-5, 1- very basic, 2- somewhat basic, 3- reasonable, 4- good, 5- very good	
5	How would you rate your overall ability to obtain conventional echocardiographic images **prior to** participating in this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
6	How would you rate your overall ability to obtain conventional echocardiographic images **at the end** of this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
7	How would you rate your overall ability to perform Doppler imaging **prior to** participating in this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
8	How would you rate your overall ability to perform Doppler imaging **at the end** of this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
9	How would you rate your overall ability to interpret echocardiographic studies and reach a diagnosis **prior to** participating in this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
10	How would you rate your overall ability to interpret echocardiographic studies and reach a diagnosis **at the end** of this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	

(*Continued*)

Appendix 3 (*Continued*)

No	Question	Your response
11	How would you rate your overall ability to correctly diagnose and quantify LV systolic dysfunction **prior to** participating in this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
12	How would you rate your overall ability to correctly diagnose and quantify LV systolic dysfunction **at the end** of this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
13	How would you rate your overall ability to correctly diagnose and quantify major valve lesions **prior to** participating in this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
14	How would you rate your overall ability to correctly diagnose and quantify major valve lesions **at the end** of this activity? Rate on a scale of 1-5, 1- completely unconfident, 2- somewhat unconfident, 3- neutral, 4- somewhat confident, 5- very confident	
15	What was your mode of training at Medanta- 1. On-site; 2. Remote through internet	
Following questions are only for those who underwent remote echocardiographic training		
16	How satisfied you were with your overall experience during the training? Rate on a scale of 1-5, 1- completely dissatisfied, 2- somewhat dissatisfied, 3- Neutral, 4- somewhat satisfied, 5- completely satisfied	
17	How satisfied you were with the video quality? Rate on a scale of 1-5, 1- completely dissatisfied, 2- somewhat dissatisfied, 3- Neutral, 4- somewhat satisfied, 5- completely satisfied	
18	How satisfied you were with the audio quality? Rate on a scale of 1-5, 1- completely dissatisfied, 2- somewhat dissatisfied, 3- Neutral, 4- somewhat satisfied, 5- completely satisfied	
19	How satisfied you were with your interaction with the remote trainer? Rate on a scale of 1-5, 1- completely dissatisfied, 2- somewhat dissatisfied, 3- Neutral, 4- somewhat satisfied, 5- completely satisfied	
20	Do you think that remote, internet-based training can be an effective solution where on-site trainer is not available? Rate on a scale of 1-5, 1- Completely unacceptable, 2- unacceptable, 3- Neutral, 4- acceptable, 5- very much acceptable	