American Society of Echocardiography: Remote Echocardiography with Web-Based Assessments for Referrals at a Distance (ASE-REWARD) Study

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Background: Developing countries face the dual burden of high rates of cardiovascular disease and barriers in accessing diagnostic and referral programs. The aim of this study was to test the feasibility of performing focused echocardiographic studies with long-distance Web-based assessments of recorded images for facilitating care of patients with cardiovascular disease.

Methods: Subjects were recruited using newspaper advertisements and were prescreened by paramedical workers during a community event in rural north India. Focused echocardiographic studies were performed by nine sonographers using pocket-sized or handheld devices; the scans were uploaded on a Web-based viewing system for remote worldwide interpretation by 75 physicians.

Results: A total of 1,023 studies were interpreted at a median time of 11:44 hours. Of the 1,021 interpretable scans, 207 (20.3%) had minor and 170 (16.7%) had major abnormalities. Left ventricular systolic dysfunction was the most frequent major abnormality (45.9%), followed by valvular (32.9%) and congenital (13.5%) defects. There was excellent agreement in assessing valvular lesions (κ = 0.85), whereas the on-site readings were frequently modified by expert reviewers for left ventricular function and hypertrophy (κ = 0.40 and 0.29, respectively). Six-month telephone follow-up in 71 subjects (41%) with major abnormalities revealed that 57 (80.3%) had improvement in symptoms, 11 (15.5%) experienced worsening symptoms, and three died.

Conclusions: This study demonstrates the feasibility of performing sonographer-driven focused echocardiographic studies for identifying the burden of structural heart disease in a community. Remote assessment of echocardiograms using a cloud-computing environment may be helpful in expediting care in remote areas. (J Am Soc Echocardiogr 2013;26:221-33.)

Keywords: Telemedicine, Portable ultrasound, Community outreach, Echocardiography

Technological advancements in ultrasound imaging have allowed the miniaturization of ultrasound units, making them portable enough to be carried to remote communities.[1-3] Previous investigations have demonstrated the utility of portable cardiac ultrasound systems in several clinical disciplines.[1-3] Furthermore, Web-based transmission solutions have made it possible to perform tests at remote locations and to have consultations, in real time, by experts at a distance.[4-9] Although feasibility to guide cardiac care through remote echocardiographic assessment has been demonstrated,[5,7-12] there is limited information regarding the large-scale integration of Web-based modules for assessing focused echocardiograms obtained in rural communities.

The increased affordability and portability of cardiac ultrasound systems may allow the targeted use of focused cardiac ultrasound

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Drs. Singh and Bansal contributed equally to this work. For a detailed list of ASE-REWARD study investigators, please refer to Appendix 1.

GE Healthcare provided a grant in support of this project. Equipment and on-site technical support were provided by GE Healthcare and Core Sound Imaging, Inc. Ms. Dantin is employed by GE Healthcare and Dr. Smith is employed by Core Sound Imaging, Inc. The remaining authors have no conflicts of interest to disclose.

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0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2012.12.012

Abbreviations

CVD = Cardiovascular disease

LV = Left ventricular

LVEF = Left ventricular ejection fraction

in health missions to remote areas of the developing world and the rapid assessment of patients with suspected cardiovascular compromise. This is particularly relevant for developing countries such as India, where people are experiencing the dual burden of high rates of cardiovascular disease (CVD) and barriers to accessing diagnostic testing and referrals to appropriate cardiovascular specialists.[13-16] In late January 2012, the American Society of Echocardiography developed a community outreach project in a rural setting in northwestern India. Physicians and sonographers were invited as volunteers to perform focused echocardiographic studies and were supported by long-distance Web-based consulting to facilitate appropriate care and referral of patients with CVD. The knowledge gained from the design, development, and evaluation of this project has been compiled in this report with the intention of illustrating the potential of remote, real-time echocardiography using Web-based integration of services for mass triage.

METHODS

This study was undertaken as part of a free cardiac health checkup camp that is held annually during a community congregation for mass meditation in a remote rural community in northern India (Figure 1). Patients were specifically alerted and invited, through a newspaper advertisement, to attend this camp if (1) they had symptoms suggestive of cardiovascular illness (e.g., chest pain, shortness of breath, swelling in the feet, dizziness, loss of consciousness) but had never been evaluated adequately, or (2) they had known CVD and were experiencing clinical deterioration, but no cardiac imaging had been performed within the previous year.

After enrollment, local paramedical workers verbally screened >10,000 patients who had gathered at the local site for several different health care projects.[17] The local volunteers verbally interrogated the groups to sort outpatients who admitted the presence of specific referral criteria for CVD to line up for echocardiographic studies. The demographic details of each eligible patient were recorded; all patients subsequently underwent a focused echocardiographic examination.

Echocardiographic Examination, Image Transfer, and Interpretation

Echocardiographic examinations were performed using pocket-sized, hand-held cardiac ultrasound units (Vscan and Vivid I or Vivid Q portable cardiac ultrasound systems; GE Medical Systems, Milwaukee, WI). Scans were performed by volunteer sonographers trained to execute a protocol consisting of 11 standard views, including color-flow Doppler images of all valves (Appendix 2). The Vscan is a small, pocket-sized 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 images with a fixed sector width of 30°. Current-generation devices do not have the capabilities of spectral Doppler and M-mode imaging. Therefore, patients who needed additional imaging using continuous-wave or pulsed-wave Doppler to arrive at initial diagnoses were further scanned using the Vivid I or Vivid Q system. The Vivid I and Vivid Q are laptop-based, portable systems that allow more comprehensive examinations. All studies were digitally recorded in either mp3 or Digital Imaging and Communications in Medicine format.

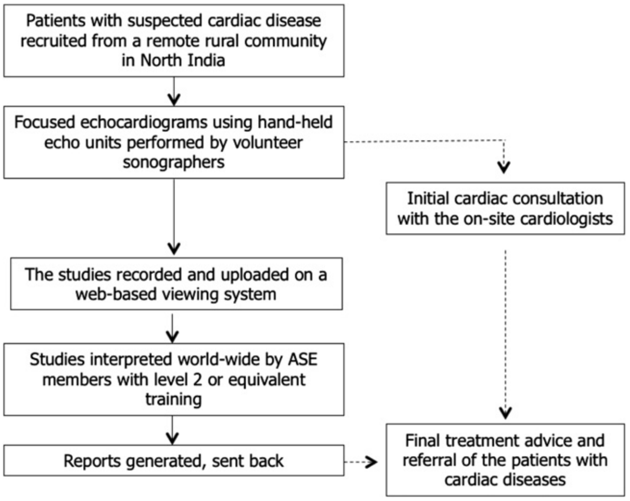

Figure 1 Study design and work flow. *ASE*, American Society of Echocardiography.

On completion of each study, a provisional echocardiographic report was generated by the scanning sonographer and given to the patient for consultation with the on-site physician or cardiologist. Studies from the camp were uploaded to a cloud-based Web server (Studycast; Core Sound Imaging, Inc., Raleigh, NC). Using commercially available software (CoreConnect; Core Sound Imaging, Inc.), the study images were acquired from the modality (GE Vscan devices at the camp) and then transmitted to the image and work flow management component (CoreWeb; Core Sound Imaging, Inc.). The studies were then securely transmitted using a broadband internet connection. CoreConnect ensured the validity of the transmitted data by applying multiple integrity checks during the transmission process. Confidentiality of the transmitted data was ensured using standard Secure Sockets Layer (Transport Layer Security) encryption while the data were in transit between CoreConnect and CoreWeb and between CoreWeb and the user. Once the study images and data were transmitted to CoreWeb, they were available for access (interpretation, report generation, etc.) by any user with valid login credentials. Worldwide interpretations were performed by 75 volunteer physicians with level 2 or 3 or equivalent training who had preregistered with the American Society of Echocardiography (Supplemental Figure 1). The study interpretations were performed using a standardized template that included information about chamber dimensions, valve morphology, color flow, global and regional left ventricular (LV) systolic function, and any apparent congenital cardiac malformations. Any other abnormality, if found, was also recorded. The reports were finalized on the Web-based system, 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 interpretations made by the on-site readers.

For the purposes of analysis and interpretation, readers were requested to give only visual, qualitative insights (mild, moderate, or severe) on specific pathologic issues: LV dilation, LV wall hypertrophy (concentric or asymmetric), reduction of LV systolic function (visual LV ejection fraction [LVEF]), right ventricular dilation, left atrial dilatation, aortic root dilatation, valve calcification, pericardial effusion, pleural effusion, and dilation with reduced inspiratory reactivity of the inferior vena cava. LVEF was considered low if it was <55% by visual estimation and graded by American Society of Echocardiography–recommended definitions for LV dysfunction as mild (LVEF, 45%–54%), moderate (LVEF, 30%–44%), or severe (LVEF < 30%) LV dysfunction.[18] We also noted segmental wall motion abnormality (yes or no) and the presence of pericardial effusion (clinically significant or not clinically significant). The presence of valvular abnormalities (regurgitant or stenotic) and their grades (mild, moderate, or 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 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 congenital heart defects (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. The quality of echocardiographic images was graded by off-site readers on a scale ranging from 1 to 4 (1 = excellent, 2 = good, 3 = fair, and 4 = poor). In addition, images were labeled as (1) technically challenging and diagnostic or (2) technically challenging and nondiagnostic.

Cardiology Consultations

Patients with abnormal echocardiographic results were examined by the on-site cardiologists, who advised patients of the appropriate treatment on the basis of the clinical findings and the provisional echocardiographic reports. If required, immediate medical attention was facilitated with the help of the local administrative and medical staff members. The initial treatment advice was later modified, if necessary, once the final echocardiographic reports became available.

Follow-Up

Patients were asked to provide their contact phone numbers (if available) at the time of enrollment. Between 6 and 7 months after the initial evaluation, we contacted by telephone the cohort of patients who had registered their phone numbers and were found to have significant cardiac abnormalities during the initial echocardiographic examinations. We inquired about their overall well-being, the response to the treatment advice given, and whether they had sought further medical attention as advised.

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 mean ± SD (or as medians and interquartile ranges if not normally distributed), and categorical data are reported as numbers and percentages. Descriptive analysis was performed to summarize the abnormal echocardiographic findings. The time intervals from scanning to study upload or interpretation were calculated and correlated with the image file size using Spearman's rank correlation coefficient. The on-site interpretation was compared with the subsequent, formal expert interpretation to determine the diagnostic accuracy of the on-site interpretation. Discordance between on-site and expert readings was recorded when an abnormality was not reported or was overreported or when difference of more than one level of severity existed. Discordance was considered as major when the discrepancy related to a major abnormality (not stated, underrated, or overreported). Kappa coefficients were calculated as the measure of agreement between the two. P values < .05 were considered significant.

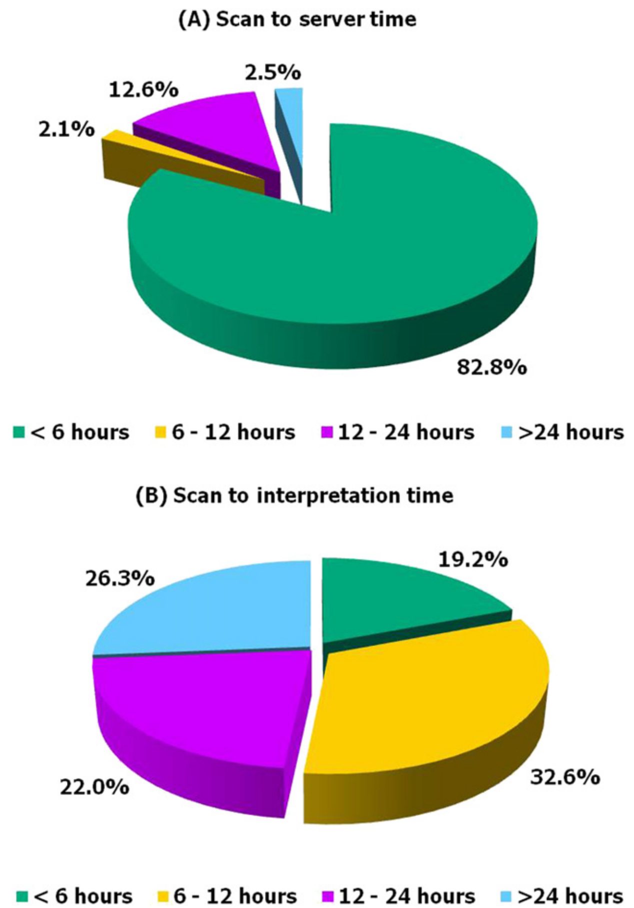

Figure 2 Time from initial scanning to study upload **(A)** and to final study interpretation **(B)**.

RESULTS

Nine sonographers performed a total of 1,023 echocardiographic studies over 2 days. The mean age of the subjects was 47.4 ± 14.4 years, and 614 (60%) were men.

Image Size, Storage, and Time to Interpretation

On average, each study consisted of 17.1 ± 5.6 clips with an average size of 5.1 ± 3.6 MB. The average upload time was 3.25 ± 1.1 min. Image file size (average, ~5.1 MB) was the primary determinant of upload time (Spearman's $\rho = 0.83$, $P < .001$). The average time delay from scanning to image upload was 3:59 ± 6:02 hours (median, 1:35 hours; interquartile range, 0:56–2:40 hours) and from scanning to final interpretation was 16:56 ± 13:51 hours (median, 11:44 hours; interquartile range, 7:23–25:46 hours) (Figure 2).

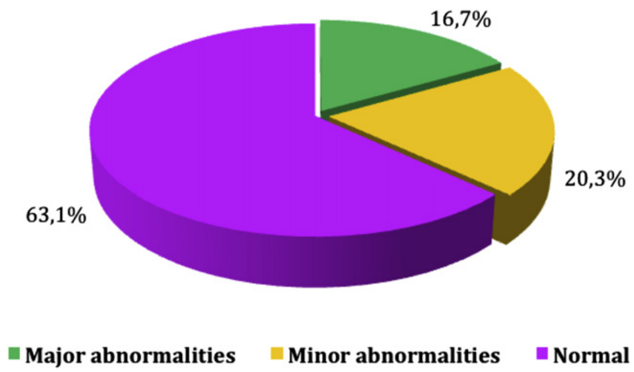

Figure 3 Distribution of the abnormal scans in the study subjects.

Echocardiographic Findings

Overall, only 44 of the scans (4.3%) were graded to have poor image quality. In addition, the readers made specific comments while interpreting 103 scans (10.0%), of which 35 were graded as technically challenging and diagnostic images and 34 had limited views. Of the remaining 876 scans (85.6%), 434 (42.4%), 227 (22.1%), and 215 (21.0%) were graded to have excellent, good, and fair image quality, respectively. For two scans, poor image quality precluded interpretation. The echocardiographic findings are therefore compiled for the remaining 1,021 scans. Of these 1,021 scans, 644 (63.1%) were interpreted as normal, 207 (20.3%) had minor abnormalities, and 170 (16.7%) had major abnormalities (Figure 3). The pattern and distribution of the major and minor cardiac abnormalities in these scans are summarized in Tables 1 and 2.

LV Systolic Dysfunction. LV systolic dysfunction, reported in 78 subjects (71 with predominant LV systolic dysfunction and another seven with LV systolic dysfunction in association with valvular diseases), was the most common major cardiac abnormality (45.9% of subjects with major abnormalities). More than two thirds of the patients with predominant LV systolic dysfunction (49 patients [70%]) had regional wall motion abnormalities, while the remaining patients had global LV systolic dysfunction. Global LV function was reported to be moderately or severely reduced in 35 patients.

Valvular Heart Disease. Overall, 56 patients (32.9%) had significant valvular heart disease (Table 3, Figure 4, Videos 1, 1B, 2A, 2B, 3A, and 3B; available at www.onlinejase.com); of these, 73.2% had mitral valve disease, 12.5% had aortic valve disease, and 10.7% had mixed valve disease. Mitral stenosis was the most common mitral valve abnormality (occurring in two thirds of all patients with mitral valve disease). Seven patients also had concomitant significant LV systolic dysfunction. Minor valvular abnormalities were seen in 129 patients (12%), with mild mitral regurgitation being the most frequently reported abnormality.

Congenital Heart Disease. Twenty-three patients (2.3% of the total and 13.5% of those with major echocardiographic abnormalities) presented with congenital heart defects (Table 4, Figure 5, Videos 4A–4C, 5A, and 5B). Ventricular septal defect was the most common anomaly and was identified in 10 patients (in seven patients, the anomaly was isolated, two had tetralogy of Fallot, and one had a double-outlet right ventricle). Five patients had atrial septal defects, three had patent ductus arteriosus, two had bicuspid aortic valves (associated with at least one other major anomaly), and two had aneurysms of the sinus of Valsalva (one ruptured). In five patients, congenital heart defects were suspected, but data were insufficient for confirmation (ventricular septal defects in two patients, an atrial septal defect in one patient, Ebstein's anomaly in one patient, and coarctation of the aorta in one patient).

Asymmetric Septal Hypertrophy. Eleven patients (1.1%) had asymmetric septal hypertrophy. Five of these patients had significant asymmetric septal hypertrophy with features suggestive of LV outflow tract obstruction with systolic anterior motion of the mitral leaflets. Six other patients had mild asymmetric septal hypertrophy.

Table 1 Major echocardiographic abnormalities in the study patients (*n* = 170)

Echocardiographic abnormality	*n* (%)
Predominant valvular heart disease	49 (28.8)
Predominant LV systolic dysfunction	71 (41.8)
Regional	49 (28.8)
Global	22 (12.9)
Mixed valve disease and LV systolic dysfunction	7 (4.1)
Congenital heart disease*	23 (13.5)
Right-heart enlargement/pulmonary hypertension	9 (5.3)
Other abnormalities	12 (7.1)
Asymmetric septal hypertrophy	5 (2.9)
Concentric LV hypertrophy	3 (1.8)
Left atrial enlargement	3 (1.8)
Abnormal septal motion suggesting constrictive pericarditis	1 (0.6)

Patients were assigned particular diagnostic categories on the basis of the most dominant abnormality found. When a patient had more than one severe abnormality, he or she was placed in all the relevant categories.
*Five more patients had questionable evidence of congenital heart disease.

Table 2 Minor echocardiographic abnormalities in the study patients (*n* = 207)

Echocardiographic abnormality	*n* (%)
Valvular heart disease	128 (61.8)
LV hypertrophy	53 (25.6)
Left atrial enlargement	46 (22.2)
Aortic root enlargement	14 (6.8)
Others abnormalities	19 (9.2)
Isolated right-heart enlargement	5 (2.4)
Suspected bicuspid aortic valve	4 (1.9)
Suspected atrial septal defect or patent foramen ovale	3 (1.4)
Mild pericardial effusion	3 (1.4)
Prosthetic heart valve	2 (1.0)
Others	2 (1.0)

Numbers are not mutually exclusive, because many patients had more than one echocardiographic abnormality.

Incremental Value of Expert Interpretation

The on-site sonographer and remote expert interpretations were compared for the 555 echocardiographic studies performed on the first day of the camp (Table 5). Overall, 409 studies (73.7%) had

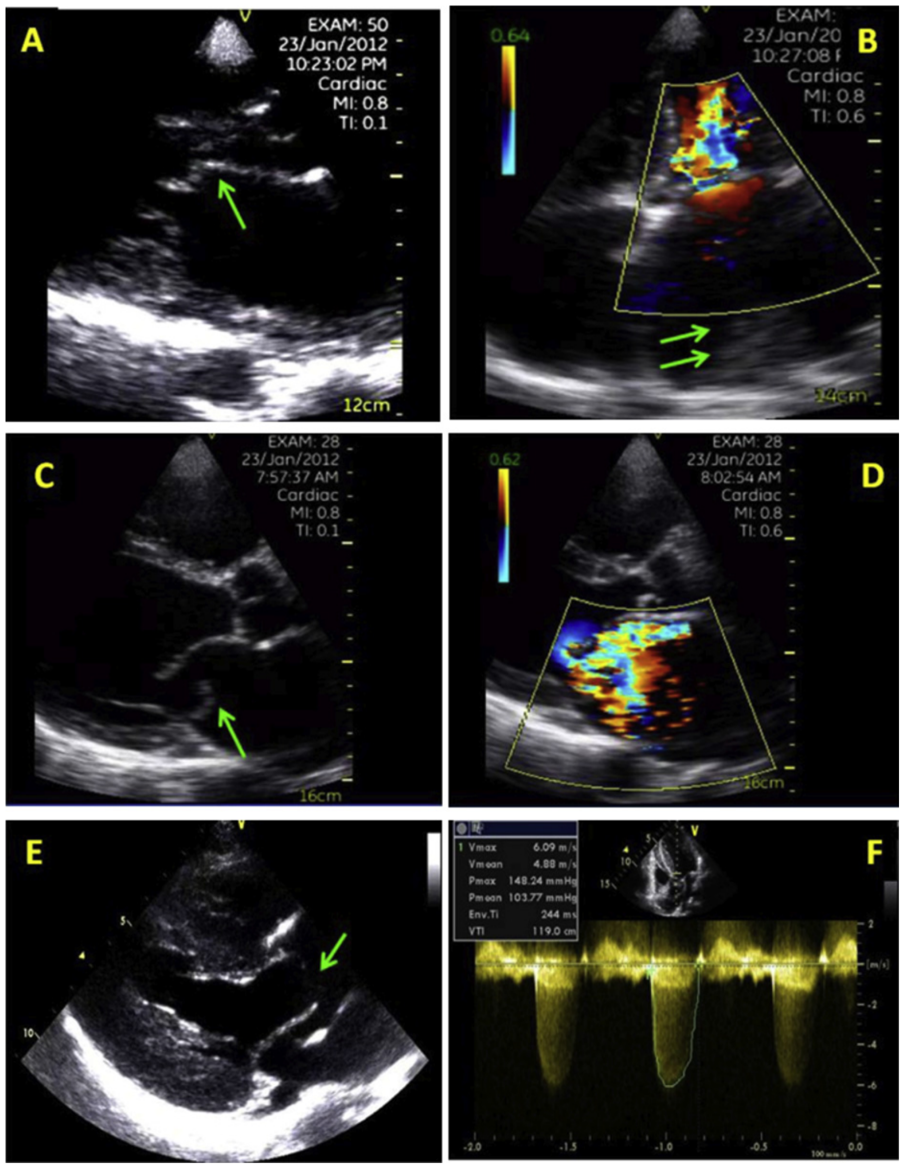

Figure 4 Illustrative examples of valvular lesions diagnosed by focused echocardiography in the camp. **(A,B)** Significant mitral stenosis with thickened mitral valve leaflets, doming of anterior mitral leaflet (*arrow*), turbulent mitral jet suggestive of elevated transmitral gradients, and left atrial thrombus (*double arrows*). **(C,D)** Flail posterior mitral leaflet (*arrow*) with anteriorly directed, eccentric severe mitral regurgitation. **(E,F)** Severe aortic stenosis as evidenced by systolic doming of aortic leaflets and markedly elevated transaortic gradients (mean gradient > 100 mm Hg).

concordant interpretations, whereas discrepancies were noted between the on-site interpretations and the expert assessments in the remaining 146 scans. In 46 subjects, findings reported by the expert readers were not reported by the on-site sonographers, whereas in 100 patients, lesions thought to be present by the on-site sonographers were not appreciated by the expert readers. For 78 scans (53.4%), the discrepancies were for lesions considered to be major by the expert readers.

Agreement was greatest for valvular heart disease, with on-site interpretations having sensitivity and specificity of 0.83 and 0.99 and a κ value of 0.85. Performance was only modest for the assessment of LV systolic function and hypertrophy ($\kappa = 0.4$ and 0.29, respectively, Table 5). There was no relationship between image quality and diagnostic accuracy. Of the 146 scans with discrepant findings, 123 (85.4%) had fair to excellent image quality, which was similar to the studies with concordant results ($P = .86$ for comparison).

Follow-Up

Follow-up information was obtained for 71 of the 102 patients (70.0%) with significant echocardiographic abnormalities who had their phone numbers registered at the time of the initial screening. Of these 71 patients, 37 (52.1%) had already sought further medical attention as advised after the initial echocardiographic assessment and had derived symptomatic benefit. Another 20 patients (28.2%) had improved after following the initial treatment recommendations and were planning further follow-up appointments. A total of 11 patients (15.5%) had not followed initial treatment recommendations

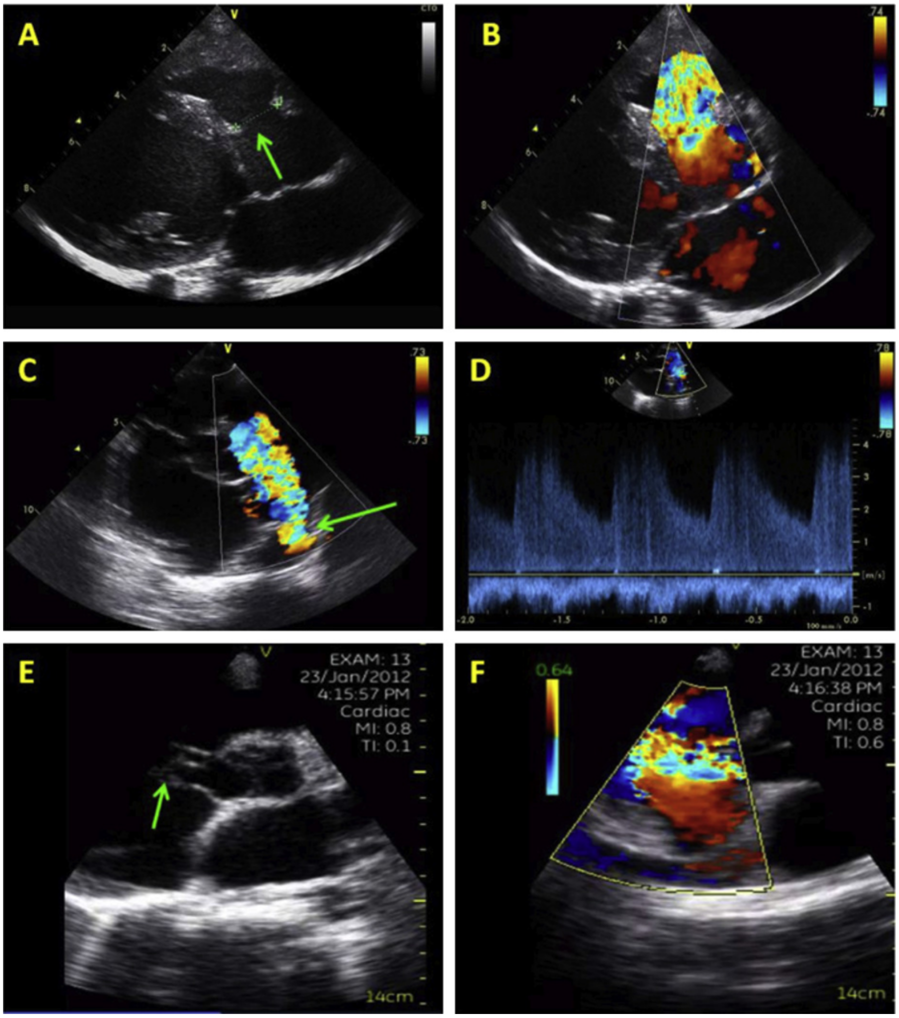

Figure 5 Illustrative examples of congenital heart defects diagnosed by focused echocardiography in the camp. **(A,B)** Large ventricular septal defect (*arrow*) with left-to-right shunt across the defect. **(C,D)** Patent ductus arteriosus evidenced by a color-flow jet in to the left pulmonary artery (*arrow*) with a continuous left-to-right shunt on spectral display. **(E,F)** Aneurysm of the noncoronary sinus of Valsalva (*arrow*) with rupture in to the right atrium resulting in large left-to-right shunt.

and were experiencing worsening of their symptoms. As a result, these patients were provided appointments for further follow-up. A total of three patients had died during the follow-up period. Of these, two patients had been noted to have significant enlargement of the right atrium and right ventricle, with features suggestive of severe pulmonary hypertension. The third patient who had died during the follow-up period had mild mitral stenosis and suspected bicuspid aortic valve with coarctation of the aorta.

DISCUSSION

To the best of our knowledge, this study represents the largest attempt to perform focused echocardiographic studies in a community to triage >1,000 patients within a period of 48 hours. The limited scanning protocol used in this study ensured that the study size was small enough to permit rapid and seamless uploading of the images to the Web-based system. At the same time, analysis of the study findings confirmed the adequacy of the concise, limited scanning protocol in capturing the relevant data required for appropriate triaging of the patients. The scanning was assisted by remote interpretation by 75 physicians worldwide, and major abnormalities were identified in 170 patients (16.7%). Subsequent telephone follow-up in 71 patients with major abnormalities at 6 months revealed that approximately 80% of patients were compliant with the initial recommendations and satisfied with the initial care.

Despite technological advancements, a wide disparity exists, in terms of health care infrastructure, between the privileged and the underprivileged sections of society. The differences are most apparent in developing nations such as India, where health care resources are largely concentrated in affluent, urban communities and where rural communities lack access to the most basic health care facilities.[15,16] Wide disparities in cardiac screening and disease detection have also been reported in specific communities in developed countries where racial, ethnic, and socioeconomic disparities exist.[19] The use of cardiac ultrasound for early detection of subclinical, manifest cardiac disease has been recommended. Although challenges remain, one of the suggested ways to improve detection has been to combine cardiac ultrasound with telemedicine, for which initial experiences have been promising.[5-12] The transfer of images over the internet for expert interpretation is a common practice at centers that have imaging capabilities but lack the necessary expertise required

Table 3 Significant valvular heart disease in the study patients (n = 56)

Valvular heart disease	n (%)
Predominant mitral valve disease	41 (73.2)
Stenosis	23 (41.1)
Regurgitation	14 (26.8)
Both	3 (5.4)
Predominant aortic valve disease	7 (12.5)
Stenosis	1 (1.8)
Regurgitation	3 (5.4)
Both	3 (5.4)
Predominant tricuspid valve disease	2 (3.6)
Regurgitation	2 (3.6)
Mixed valvular heart disease	6 (10.7)

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

Table 4 Congenital heart disease in the study patients (n = 23)

Congenital heart disease	n (%)
Atrial septal defect	5 (21.7)
Ventricular septal defect	10 (43.5)
Isolated	7 (30.4)
Tetralogy of Fallot	2 (8.7)
Double outlet right ventricle	1 (4.3)
Patent ductus arteriosus	3 (13.0)
Bicuspid aortic valve	2 (8.7)
Severe aortic stenosis	1 (4.3)
Dilated aortic root and ascending aorta	1 (4.3)
Sinus of Valsalva aneurysm	2 (8.7)
Ruptured	1 (4.3)
Unruptured	1 (4.3)
Cleft mitral leaflet	1 (4.3)

In addition, there were five more patients with suspected congenital heart disease (two with ventricular septal defects, one with an atrial septal defect, one with Ebstein's anomaly, and one with coarctation of the aorta).

for the interpretation of those studies.[5,7,8,12,20-23] With echocardiography, such an approach has been used primarily in pediatric populations to rule out significant congenital heart diseases. Both store-and-forward and real-time transmission approaches have been tried using different technologies and data transmission speeds. These studies have clearly demonstrated that remote echocardiography can successfully allow accurate diagnosis, thereby facilitating the appropriate care of patients, while providing cost-saving potential.[5,7,8,12,20-23] However, none of these previous studies explored the feasibility of remote echocardiography for mass triage in a community setting. This is the first study to illustrate that the strategy of performing focused echocardiographic studies in a remote, rural community with long-distance Web-based reporting is not only feasible but also effective in facilitating appropriate care and referral of patients with cardiac diseases. The focused echocardiograms were able to characterize high-risk cardiac structural changes that are associated with poor outcomes. For example, two-dimensional echocardiographic features of right ventricular enlargement and/or

Table 5 Agreement between the on-site interpretations and the remote expert interpretations of the echocardiography studies performed on the first day of the camp

Nature of the abnormality*	Sensitivity of the on-site read	Specificity of the on-site read	κ†
All studies (n = 555)	0.73	0.77	0.42
Studies with major abnormalities (n = 71)	0.73	0.88	0.49
Valvular heart disease (n = 64)	0.83	0.99	0.85
LV systolic dysfunction (n = 76)	0.69	0.92	0.40
LV hypertrophy (n = 48)	0.60	0.94	0.29

*Congenital heart disease was not included in the analysis, because the number of cases was small.
†All P values <.001.

pulmonary hypertension were seen in nine patients (5.3% with major abnormalities), and during follow-up, two of these patients died. Identification of such high-risk two-dimensional echocardiographic features should warrant rapid referral to experienced centers.

Community-based cross-sectional studies in rural populations of developing countries such as India have seen a steady increase in the prevalence of coronary artery disease risk factors, with current estimates of coronary artery disease ranging from 3.1% to 7.4%. At the same time, rheumatic valvular heart disease remains prevalent, with current adult population estimates ranging from 0.06% to 0.5%.[24] For the present study, we identified structural heart disease in 377 patients (36%) who reported symptoms suspected to be of cardiac origin. Although these numbers are higher than prevalence estimates for rural communities, these estimates differ primarily because patients for this camp had self-referred themselves. As such, these convenience sampling methods differ from population-based recruiting methods (e.g., random-digit dialing or household area sampling) with proper preselection that attempt to recruit a population that has fewer biases that come from the effects of volunteering. A potential bias therefore in patient selection for the present study cannot be eliminated. However, similar clinical programs offered through professional societies and the use of screening tests in mass congregations has been successfully used in the early detection and treatment of chronic diseases such as cancer.[25,26] Activities in mass congregations can be potentially cost effective and help accomplish screening tasks efficiently. Moreover, working within the communities with motivated groups also improves provisions for support systems using microfinance schemes for prioritizing the care of an ailing subject.

This study also demonstrated an opportunity to evaluate the role of interpretation by an expert for ensuring an acceptable level of accuracy with point-of-care echocardiography. The miniaturization of echocardiographic equipment over the past decade has increased its accessibility and availability for rapid screening assessment at the bedside and in remote community settings. Previous studies have demonstrated that the addition of a screening echocardiographic examination to the clinical assessment significantly increases diagnostic accuracy, reduces unwarranted diagnostic and treatment referrals, and facilitates the optimum utilization of health care resources.[27-29] Given these findings and the ease of use with these devices, there has been an increasing call for their widespread adoption in routine clinical practice by noncardiologists and general physicians. However, such an approach carries the risk for misuse of the technology with potential mismanagement, unless adequate

Table 6 Major studies evaluating the diagnostic accuracy and utility of echocardiography performed using pocket-sized imaging devices

Study	*n*	Study population/setting	POC setup (device, personnel)	Reference standard	Salient findings
Prinz *et al.*[30]	349	Consecutive patients referred for echocardiography at a tertiary hospital	Vscan; experienced cardiologist	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities, including LV dimensions, LV systolic function, valve lesions, etc.
Choi *et al.*[35]	89	A humanitarian mission in a remote community	Vscan; nonexpert cardiology fellow	Same images reviewed by the expert echocardiographers on a workstation and on a smart phone	The on-site diagnosis was altered by the expert interpreter in 38% cases; excellent concordance between workstation-based and smart phone–based interpretation by the same expert
Galderisi *et al.*[31]	304	Endocrinology and oncology patients referred for cardiac consultations; patients with known cardiac illnesses were excluded	Vscan; 102 scans by experts and 202 by trainees	Complete study performed on high-end echocardiographic equipment	Overall κ value between pocket-sized device and standard examination = 0.67 (0.84 for experts, 0.58 for trainees)
Testuz *et al.*[38]	104	Patients requiring urgent echocardiogram at a tertiary hospital	Vscan; experienced cardiologist	Complete study performed on high-end echocardiographic equipment	Excellent agreement ($\kappa > 0.8$) for LV systolic function and pericardial effusion, good or modest agreement ($\kappa > 0.55$) for valve lesions (all lesions were semiquantitatively scored)
Cardim *et al.*[28]	189	Patients referred for cardiac outpatient consultations	Vscan; experienced cardiologists	None	Addition of POC imaging significantly improved diagnostic accuracy and reduced unnecessary echocardiographic referrals
Andersen *et al.*[32]	108	Patients admitted to medical department at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities including LV systolic function, right ventricular function, pericardial effusion, valve lesions, etc.
Skjetne *et al.*[29]	119	Patients admitted to a cardiac unit at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy
Lafitte *et al.*[33]	100	Patients referred for echocardiography for conventional clinical indications	Vscan; experienced physician blinded to results of standard examination	Complete study performed on a high-end echocardiographic system	Excellent concordance for majority of the abnormalities
Liebo *et al.*[36]	97	Patients referred for echocardiography for conventional clinical indications	Vscan; images interpreted by two experienced echocardiographers and two cardiology fellows	Complete study performed on a high-end echocardiographic system	Accuracy varied according to the type of the abnormality and the level of experience; overall, accuracy was highest for LV systolic function
Michalski *et al.*[37]	220	Consecutive patients undergoing echocardiography (110 inpatient, 110 outpatient)	Vscan; a cardiology resident (second year of training) and an experienced cardiologist	Complete study performed on a high-end echocardiographic system	Concordance for most abnormalities was moderate to very good for the resident and good to excellent for the experienced cardiologist

Biais *et al.*[34]	151	Patients admitted to the emergency department and requiring echocardiography	Vscan; experienced echocardiographer	Complete study performed on a high-end echocardiographic system	Excellent concordance ($\kappa > 0.8$) for most parameters
Prinz *et al.*[39]	320	Consecutive patients referred for echocardiography at a tertiary hospital	Vscan; inexperienced echocardiographer	Complete study performed on a high-end echocardiographic system	Image quality and diagnostic accuracy showed significant improvement over the 8-week period over which patients were recruited
Fukuda *et al.*[40]	125	Patients undergoing echocardiography for various indications	Acuson P10; experienced echocardiographer	Complete study performed on a high-end echocardiographic system	Excellent correlation and agreement for cardiac chamber size and function
Mjolstad *et al.*[27]	196	Patients admitted to medical department at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on a high-end echocardiographic equipment	Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy
Panoulas *et al.*[41]	122	Cardiology patients	Vscan; inexperienced echocardiographers	Complete study performed on high-end echocardiographic equipment	Addition of POC imaging significantly improved diagnostic accuracy

Only studies with ≥75 patients are included.
POC, Point-of-care.

education is provided to ensure the competence level of the operator. Previous studies that demonstrated excellent diagnostic accuracy with pocket-sized echocardiographic devices involved experienced echocardiographers,[27,30-34] whereas accuracy was suboptimal in the hands of trainees and inexperienced echocardiographers[31,35-37] (Table 6[38-41]). In line with these observations, the recently published position statement of the European Association of Echocardiography highlights the specific use of pocket-sized devices and mandates specific training and certification for all users, with the exception of cardiologists who are certified for transthoracic echocardiography according to national legislation. In addition, the recommendations emphasize that the certification should be limited to the clinical questions that can potentially be answered by these devices.[42] In our study, we found that even with experienced sonographers, the on-site diagnoses required modification in almost one fourth of all patients, and in almost half, the alterations were of major diagnostic significance. In addition, although the accuracy for detection of valvular lesions was comparable with that reported in previous studies, it was only modest for LV systolic dysfunction and hypertrophy. It is likely that the fast-paced activity that is typical of a camp had an overriding influence on the accuracy of the diagnoses, which were largely subjective and therefore were prone to inconsistencies. Hence, it is imperative to have a check mechanism in place in the form of a second interpretation by an experienced echocardiographer to ensure the desired level of accuracy.

Limitations

In the present study, scanning was performed using handheld echocardiographic systems using a limited imaging protocol to allow rapid scanning and smooth uploading of the acquired images. As a result, detailed evaluations could not be performed in many of the patients, which at times precluded complete diagnoses and may have affected the appropriate triaging of the patients. Moreover, because follow-up as of this writing had been accomplished in only a small minority of patients, and follow-up data from the referral centers were not available at the time of the present analysis, the overall efficacy of the referral strategies might be underestimated. Similarly, for logistical reasons, we were unable to determine the proportion of patients for whom echocardiography was helpful in modifying preexisting diagnosis from those patients who had communicated that they had been previously diagnosed with cardiac disease. However, the overall goal of the study was to demonstrate the feasibility of remote echocardiographic assessment and the incremental value of using Web-based remote assessment for facilitating appropriate mass triage of patients with suspected cardiac illnesses. This goal was successfully accomplished in the present study.

In the present study, the on-site echocardiographic diagnoses were compared with subsequent expert reviews of the same set of images. For logistical reasons, it was not possible to perform comprehensive echocardiographic examinations in these subjects. Therefore, the possibility of some misdiagnoses cannot be excluded. However, numerous previous studies have clearly demonstrated that when used by experienced echocardiographers, excellent diagnostic accuracy can be achieved with these pocket-sized devices, comparable with traditional stationary equipment.[27,30,32-34] In addition, we used a visual, qualitative approach for the diagnosis and grading of various echocardiographic abnormalities, which added subjectivity to the interpretations and may have influenced the agreement between the on-site sonographers and the remote expert readers. However, a similar approach has been used in previous studies involving experienced echocardiographers and has shown good to excellent correlation with the findings on subsequent comprehensive echocardiographic studies.[29,32,38]

CONCLUSIONS

This study demonstrates the feasibility of using remote echocardiography with Web-based integration of services for mass triage. Resource integration and assessment of focused echocardiograms using a cloud-computing environment may be helpful in expediting care in remote areas.

ACKNOWLEDGMENT

The ASE-REWARD team would like to specially thank his Excellency Reverend Saint Gurmeet Ram Rahim Singh ji Insan, Dera Sacha Sauda, Sirsa, Haryana for motivating the masses and encouraging the investigators for organizing this humanitarian activity. We would like to thank Dr. Daniela Borges, MD. and Mr. Sherwin Najera for their help in compiling the data and for editorial assistance.

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APPENDIX 1

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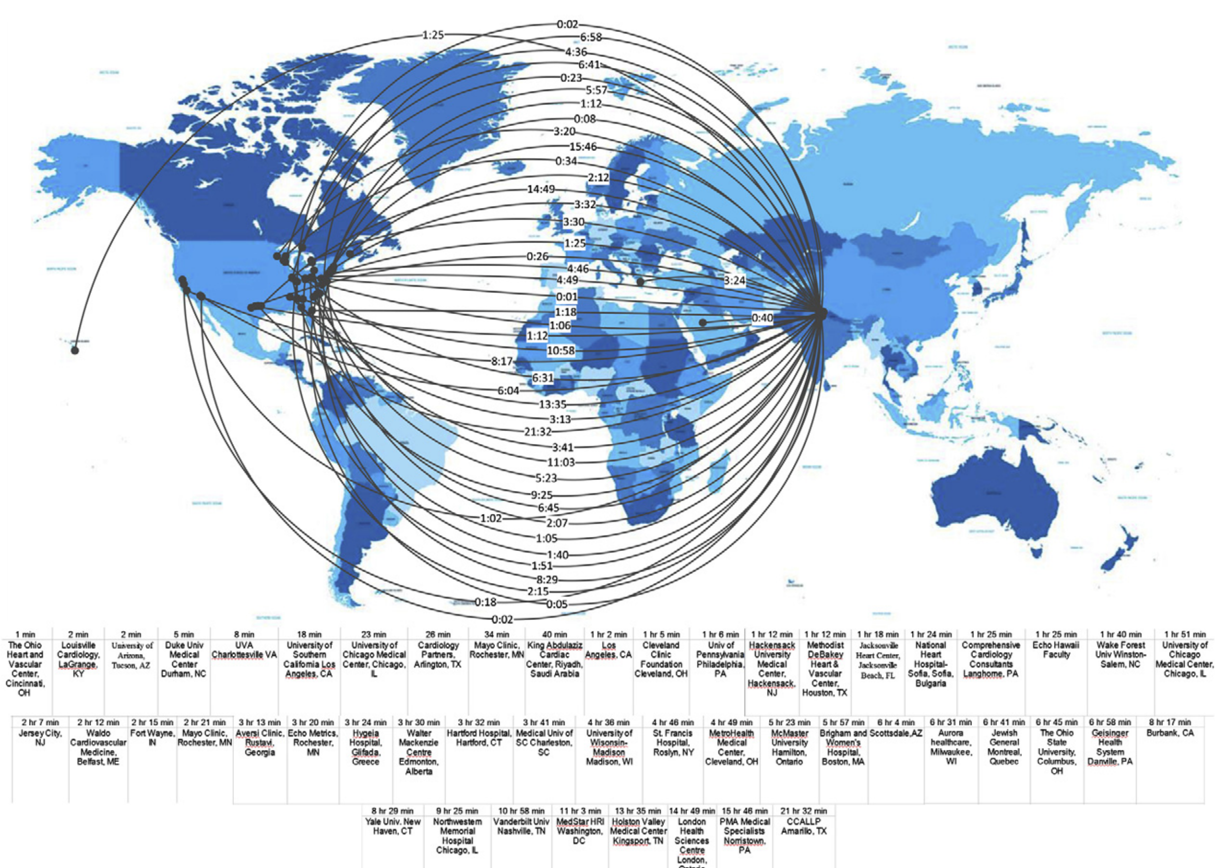
APPENDIX 2

Echocardiographic scanning protocol used in the study

Vscan echocardiographic imaging protocol
Voice-record patient's name and study number on the Vscan; verify on worksheet
1. PSLAX: 2D
2. PSLAX: color (for assessing aortic and mitral regurgitation)
3. PSAX at AOV level: 2D
4. PSAX at AOV level: color
5. PSAX at MV level (visualize MV orifice)
6. PSAX at MV level: Color
7. PSAX at PAP level
8. Four-chamber: 2D (full visualization of atria and ventricles)
9. Four-chamber: color mitral regurgitation
10. Four-chamber: color tricuspid regurgitation
11. Five-chamber: color aortic regurgitation
12. Additional images in the event a lesion is profiled

AOV, Aortic valve; *MV*, mitral valve; *PAP*, papillary muscle; *PSAX*, parasternal short-axis view; *PSLAX*, parasternal long-axis view; *2D*, two-dimensional.



Supplemental Figure 1 Schematic representation of the geographic location of the expert readers in relation to the study site in northern India.