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 ($k = 0.85$), whereas the on-site readings were frequently modified by expert reviewers for left ventricular function and hypertrophy ($k = 0.40$ 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. Previous investigations have demonstrated the utility of portable cardiac ultrasound systems in several clinical disciplines. 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.

Although feasibility to guide cardiac care through remote echocardiographic assessment has been demonstrated, 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...
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. 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 mediation 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. 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.

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 workflow 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.\textsuperscript{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, hypodynamic 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 a 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.

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, \( \sim 5.1 \) 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).
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 interpretable 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 1B, 2B, 3B, and 3D; 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 defect, 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.

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...
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 $\kappa$ 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 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).
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

**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 into 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 into the right atrium resulting in large left-to-right shunt.
for the interpretation of those studies. 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. Both store-and-forward and real-time transmission approaches have been tried using different technologies and data transmission speeds.

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

<table>
<thead>
<tr>
<th>Valvular heart disease</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant mitral valve disease</td>
<td>41 (73.2)</td>
</tr>
<tr>
<td>Stenosis</td>
<td>23 (41.1)</td>
</tr>
<tr>
<td>Regurgitation</td>
<td>14 (26.8)</td>
</tr>
<tr>
<td>Both</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Predominant aortic valve disease</td>
<td>7 (12.5)</td>
</tr>
<tr>
<td>Stenosis</td>
<td>1 (1.8)</td>
</tr>
<tr>
<td>Regurgitation</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Both</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Predominant tricuspid valve disease</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>Regurgitation</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>Mixed valvular heart disease</td>
<td>6 (10.7)</td>
</tr>
</tbody>
</table>

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)

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

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. 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. 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 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.

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

<table>
<thead>
<tr>
<th>Nature of the abnormality*</th>
<th>Sensitivity of the on-site read</th>
<th>Specificity of the on-site read</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>All studies (n = 555)</td>
<td>0.73</td>
<td>0.77</td>
<td>0.42</td>
</tr>
<tr>
<td>Studies with major</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>abnormalities (n = 71)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>0.83</td>
<td>0.99</td>
<td>0.85</td>
</tr>
<tr>
<td>LV systolic dysfunction</td>
<td>0.69</td>
<td>0.92</td>
<td>0.40</td>
</tr>
<tr>
<td>LV hypertrophy (n = 48)</td>
<td>0.60</td>
<td>0.94</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*Congenital heart disease was not included in the analysis, because the number of cases was small.

†All P values <.001.

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%. Despite 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. 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.
<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Study population/setting</th>
<th>POC setup (device, personnel)</th>
<th>Reference standard</th>
<th>Salient findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prinz et al.</td>
<td>349</td>
<td>Consecutive patients referred for echocardiography at a tertiary hospital</td>
<td>Vscan; experienced cardiologist</td>
<td>Complete study performed on high-end echocardiography equipment</td>
<td>Excellent concordance for majority of the abnormalities, including LV dimensions, LV systolic function, valve lesions, etc.</td>
</tr>
<tr>
<td>Choi et al.</td>
<td>89</td>
<td>A humanitarian mission in a remote community</td>
<td>Vscan; nonexpert cardiology fellow</td>
<td>Same images reviewed by the expert echocardiographers on a workstation and on a smart phone</td>
<td>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</td>
</tr>
<tr>
<td>Galderisi et al.</td>
<td>304</td>
<td>Endocrinology and oncology patients referred for cardiac consultations; patients with known cardiac illnesses were excluded</td>
<td>Vscan; 102 scans by experts and 202 by trainees</td>
<td>Complete study performed on high-end echocardiographic equipment</td>
<td>Overall $k$ value between pocket-sized device and standard examination = 0.67 (0.84 for experts, 0.58 for trainees)</td>
</tr>
<tr>
<td>Testuz et al.</td>
<td>104</td>
<td>Patients requiring urgent echocardiogram at a tertiary hospital</td>
<td>Vscan; experienced cardiologist</td>
<td>Complete study performed on high-end echocardiographic equipment</td>
<td>Excellent agreement ($k &gt; 0.8$) for LV systolic function and pericardial effusion, good or modest agreement ($k &gt; 0.55$) for valve lesions (all lesions were semiquantitatively scored)</td>
</tr>
<tr>
<td>Cardim et al.</td>
<td>189</td>
<td>Patients referred for cardiac outpatient consultations</td>
<td>Vscan; experienced cardiologists</td>
<td>None</td>
<td>Addition of POC imaging significantly improved diagnostic accuracy and reduced unnecessary echocardiographic referrals</td>
</tr>
<tr>
<td>Andersen et al.</td>
<td>108</td>
<td>Patients admitted to medical department at a tertiary care hospital</td>
<td>Vscan; experienced cardiologists</td>
<td>Complete study performed on high-end echocardiography equipment</td>
<td>Excellent concordance for majority of the abnormalities including LV systolic function, right ventricular function, pericardial effusion, valve lesions, etc.</td>
</tr>
<tr>
<td>Skjetne et al.</td>
<td>119</td>
<td>Patients admitted to a cardiac unit at a tertiary care hospital</td>
<td>Vscan; experienced cardiologists</td>
<td>Complete study performed on high-end echocardiography equipment</td>
<td>Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy</td>
</tr>
<tr>
<td>Lafitte et al.</td>
<td>100</td>
<td>Patients referred for echocardiography for conventional clinical indications</td>
<td>Vscan; experienced physician blinded to results of standard examination</td>
<td>Complete study performed on a high-end echocardiographic system</td>
<td>Excellent concordance for majority of the abnormalities</td>
</tr>
<tr>
<td>Liebo et al.</td>
<td>97</td>
<td>Patients referred for echocardiography for conventional clinical indications</td>
<td>Vscan; images interpreted by two experienced echocardiographers and two cardiology fellows</td>
<td>Complete study performed on a high-end echocardiographic system</td>
<td>Accuracy varied according to the type of the abnormality and the level of experience; overall, accuracy was highest for LV systolic function</td>
</tr>
<tr>
<td>Michalski et al.</td>
<td>220</td>
<td>Consecutive patients undergoing echocardiography (110 inpatient, 110 outpatient)</td>
<td>Vscan; a cardiology resident (second year of training) and an experienced cardiologist</td>
<td>Complete study performed on a high-end echocardiographic system</td>
<td>Concordance for most abnormalities was moderate to very good for the resident and good to excellent for the experienced cardiologist</td>
</tr>
<tr>
<td>Study</td>
<td>Patients</td>
<td>Description</td>
<td>Equipment</td>
<td>Interpretation</td>
<td>Findings</td>
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<tr>
<td>Biais et al.</td>
<td>151</td>
<td>Patients admitted to the emergency department and requiring echocardiography</td>
<td>Vscan; experienced echocardiographer</td>
<td>Complete study performed on a high-end echocardiographic system</td>
<td>Excellent concordance (κ &gt; 0.8) for most parameters</td>
</tr>
<tr>
<td>Prinz et al.</td>
<td>320</td>
<td>Consecutive patients referred for echocardiography at a tertiary hospital</td>
<td>Vscan; inexperienced echocardiographer</td>
<td>Complete study performed on a high-end echocardiographic system</td>
<td>Image quality and diagnostic accuracy showed significant improvement over the 8-week period over which patients were recruited</td>
</tr>
<tr>
<td>Fukuda et al.</td>
<td>125</td>
<td>Patients undergoing echocardiography for various indications</td>
<td>Acuson P10; experienced echocardiographer</td>
<td>Complete study performed on a high-end echocardiographic equipment</td>
<td>Excellent correlation and agreement for cardiac chamber size and function</td>
</tr>
<tr>
<td>Mjolstad et al.</td>
<td>196</td>
<td>Patients admitted to medical department at a tertiary care hospital</td>
<td>Vscan; experienced cardiologists</td>
<td>Complete study performed on a high-end echocardiographic equipment</td>
<td>Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy</td>
</tr>
<tr>
<td>Panoulas et al.</td>
<td>122</td>
<td>Cardiology patients</td>
<td>Vscan; inexperienced echocardiographers</td>
<td>Complete study performed on high-end echocardiographic equipment</td>
<td>Addition of POC imaging significantly improved diagnostic accuracy</td>
</tr>
</tbody>
</table>

Only studies with ≥75 patients are included.

POC, Point-of-care.

**Limitations**

In the present study, scanning was performed using handheld echocardiographic systems and patient data were acquired through a limited protocol in a straightforward manner to allow rapid scoring and on-site decision making. However, the interpretation of these devices can be challenging, especially for inexperienced users. The results of this study suggest that the feasibility and accuracy of these devices may be limited in certain clinical settings, particularly in the presence of complex cardiac disease. However, the overall goal of the study was to demonstrate the potential of these devices in improving on-site echocardiographic diagnoses.

In our study, we found that even with experienced echocardiographers, the limitations of these devices are significant. Although the accuracy for detection of valvular lesions was comparable with that reported in previous studies, it was lower for LV systolic dysfunction and hypertrophy. Moreover, the accuracy for detection of wall motion abnormalities was significantly lower than that for detection of valvular lesions. In addition, although the accuracy for detection of wall motion abnormalities was significantly lower than that for detection of valvular lesions, it was still comparable with that reported in previous studies. In conclusion, the use of these devices in the clinical setting is promising, but further research is needed to evaluate their role in improving patient outcomes.

This study highlights the potential of handheld echocardiographic devices in improving on-site echocardiographic diagnoses and decision making. However, the limitations of these devices should be kept in mind when interpreting the results of this study. Further research is needed to evaluate the role of these devices in improving patient outcomes and their potential for use in the clinical setting.
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.

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APPENDIX 1

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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.