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Tablet-Based Limited Echocardiography to Reduce Sonographer Scan and Decontamination Time during the COVID-19 Pandemic

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Background: Limited assessments with handheld ultrasound have found meaningful clinical use in the care of acutely ill patients. However, there are limited data on incorporating handheld-based limited echocardiography into the echocardiography laboratory. The purpose of this study was to assess the efficacy of limited handheld tablet echocardiography as an alternative to traditional echocardiography during the coronavirus disease 2019 (COVID-19) pandemic as a means to limit exposure while providing essential clinical information.

Methods: Ninety consecutive inpatients with known or suspected COVID-19 were scanned according to laboratory COVID-19 guidelines using a limited 11- to 20-clip protocol on a tablet sonograph. The primary assessment was length of study time. Comparison data were drawn from comprehensive echocardiographic examinations ordered on intensive care patients not under COVID-19 precautions.

Results: Over a 36-day time period, a total of 91 requests were deemed to be appropriate for echocardiography on patients with suspected or confirmed COVID-19 (average age, 67 years; 64% men; mean body mass index, 32 kg/m^2). Of these, 90 (99%) examinations were performed using a handheld device, and all were deemed diagnostic and provided sufficient information for the clinical care team. Sonographer scan time decreased from an average of 24 $\pm$ 6.8 min on a traditional platform to 5.4 $\pm$ 1.9 min on a tablet.

Conclusions: Limited handheld echocardiography can be successfully implemented in the echocardiography laboratory for screening of COVID-19-related cardiac conditions. The protocol performed with handheld tablet ultrasound provides adequate diagnostic information of major cardiac complications of COVID-19 while decreasing sonographer contact and simplifying decontamination. (J Am Soc Echocardiogr 2020;33:895-9.)

Keywords: Handheld echocardiography, COVID-19, Limited echocardiography

Coronavirus disease 2019 (COVID-19) poses significant risk to those health care workers most proximate to infected patients,[1] including cardiac sonographers. The time it takes to produce a comprehensive echocardiogram, and the difficulty in decontaminating a full ultrasound platform needed to produce it, are likely to only increase the risk for sonographer infection further. Although the visual and quantitative fidelity of comprehensive echocardiography is far superior, we believe that the information gathered from patients with COVID-19 should be balanced against the risk produced by increased contact time and ultrasound platform contamination. We hypothesized that a handheld ultrasound platform used for bedside limited echocardiography would provide a safe, practical, and adequate diagnostic alternative to standard echocardiography in these patients.[2-5] Herein we report the results of a consecutive series of focused ultrasound examinations in patients with known or suspected COVID-19 using a handheld device.

METHODS

This was a retrospective, single-center, observational study performed at Hartford Hospital in Hartford, Connecticut, during the COVID-19 pandemic. Hartford Hospital is an 867-bed quaternary care regional referral center with a high-volume echocardiography laboratory performing >14,000 combined studies annually. This study was approved by the institutional review board at Hartford Hospital. In the interest of timely presentation of data given the urgency of the current crisis, a limited assessment among 90 patients was deemed adequate for analysis.

During the study period, consecutive inpatients with known or suspected COVID-19 were scanned according to new laboratory COVID-19 guidelines using a limited 11- to 20-clip protocol on a tablet sonograph (Table 1). The studies were requested by the clinical team and individually vetted as clinically appropriate by an attending echocardiographer. Per inclusion criteria, all consecutive patients

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Conflicts of interest: None.

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Abbreviations
EDV = End-diastolic volume
LV = Left ventricular
RV = Right ventricular

>18 years of age with COVID-19 or suspected COVID-19 who underwent bedside echocardiography during the study period (March 14, 2020, through April 19, 2020) were included. These echocardiograms were obtained using a handheld ultrasound device (Lumify; Philips Medical Systems, Andover, Massachusetts) and a focused protocol. The limited protocol (Figure 1) was designed to streamline echocardiographic examinations while providing diagnostic information regarding common COVID-19-related cardiac complications. The standard protocol was used in all patients unless specifically ordered for assessment of function only. Ultrasound-enhancing agents (UEA) were used for technically challenging patients per American Society of Echocardiography guidelines.[6] Images were transmitted and stored on the same digital picture archiving and communication system used for standard studies (McKesson Technology Solutions, Waltham, Massachusetts).

The control group consisted of 90 intensive care unit patients without COVID-19 who underwent comprehensive echocardiographic examinations during the same time frame as the test group. These echocardiograms were obtained using a traditional platform (EPIQ and IE33 [Philips Medical Systems] and Vivid E9 [GE Healthcare, Chicago, Illinois]) per guideline protocols.[7]

For both the control and test groups, the following variables were recorded: examination indication, length of examination, estimated ejection fraction, presence or absence of wall motion abnormalities, moderate or greater mitral regurgitation, presence or absence of pericardial effusion, and occurrence of follow-up transthoracic echocardiography. Variables were determined by review of the final clinical report. Missing interpretive fields or those deemed inadequately visualized for interpretation were categorized as such. Imaging time and number of clips were abstracted from review of the echocardiographic images, including time stamps to identify time elapsed between first and last clips. Time spent in the patient's room and decontamination time were obtained by averaging time spent with 10 patients (five per group).

Statistical analysis was performed using SPSS Statistics for Windows version 26 (IBM, Armonk, New York). Baseline characteristics are described using means for continuous variables and frequencies or percentages for categorical variables. Continuous variables were analyzed using unpaired *t* tests, and categorical variables were analyzed using either 2×2 or 2×3 contingency tables. *P* values $\leq .05$ were considered to indicate statistical significance.

Table 1 Tablet-based imaging protocol for patients with suspected or confirmed COVID-19

PLAX
PLAX color Doppler MV and AV
PSAX: great vessels
PSAX: level of papillary muscles
A4C
A4C color Doppler MV
A4C color Doppler TV
A5C
A2C
A3C
A3C or five-chamber color Doppler AV
A3C or five-chamber color Doppler MV
Subcostal four-chamber
IVC

A2C, Apical two-chamber; *A3C*, apical three-chamber; *A4C*, apical four-chamber; *A5C*, apical five-chamber; *AV*, aortic valve; *IVC*, inferior vena cava; *MV*, mitral valve; *PLAX*, parasternal long-axis; *PSAX*, parasternal short-axis; *TV*, tricuspid valve.

RESULTS

Over a 36-day period, a total of 657 transthoracic echocardiographic examinations were performed by the laboratory, including 91 performed on patients with suspected or confirmed COVID-19 (mean age, 67 ± 14 years; 64% men; mean body mass index, 32 ± 10 kg/m^2). Of these, 90 (99%) were performed using handheld devices, and one patient was determined to require comprehensive echocardiography on a traditional platform. Indications for handheld echocardiography were congestive heart failure or suspected cardiomyopathy (23%); shortness of breath or hypoxia (19%); chest pain, suspected myocarditis, or acute myocardial infarction (16%); shock, hypotension. or cardiac arrest (14%); atrial fibrillation or other atrial arrhythmia (12%); pulmonary embolism or right ventricular failure (4%); stroke (3%); pericardial effusion or suspected tamponade (2%); and miscellaneous (6%). Fifty-seven studies (63%) were performed on intubated patients. Of those studies performed with limited handheld echocardiography, all were deemed diagnostic and provided sufficient information for the clinical care team. Nine patients received UEAs to improve endocardial definition. The average body mass index in patients receiving contrast was significantly greater than in patients not receiving contrast (43 ± 25 vs 29 ± 7.7 kg/m^2, $P = .02$). There were no immediate requests for additional imaging because of inadequate studies, but a total of five patients (8%) later underwent repeat imaging, all in the context of rapid clinical decline. In the control group, seven patients (12%) underwent repeat imaging because of changes in clinical status (Table 2).

The average imaging time in the control group was 24 ± 6.8 min, compared with 5.4 ± 1.9 min in the limited handheld group ($P < .001$). The total duration of time spent in the patient's room decreased from 42 ± 5.5 to 12 ± 2.2 min with traditional echocardiography versus COVID-19-protocol echocardiography, respectively. Furthermore, the time required for the disinfection of a traditional sonograph in our study was 30 ± 3.5 min, compared with 4 ± 0.9 min to complete sterilization of the handheld system. Patients receiving UEAs had a longer average imaging time of 9 ± 5 min.

Regarding echocardiographic findings, among patients who underwent limited handheld echocardiographic studies, 80 (89%) had interpretations including the presence ($n = 22$ [28%]) or absence ($n = 58$ [72%]) of wall motion abnormalities. Ten interpretations (11%) did not comment on wall motion, compared with 12% in the standard echocardiography group. In the limited handheld group, all patients underwent color Doppler, except four patients (4%) who underwent echocardiography for function only at the request of the provider. In those 86 patients undergoing color Doppler, there was assessment of the severity of mitral regurgitation in 80 (93%), while the control group included assessment of mitral valve function in all cases ($P = .012$). There were comments on the presence or absence of pericardial effusion in all of the patients undergoing limited tablet-based echocardiography.

HIGHLIGHTS

- Handheld ultrasound is an effective alternative in patients with COVID-19.
- A majority of handheld studies are sufficient to guide management in these patients.
- Study time is markedly reduced (79% less), thereby reducing sonographer exposure.
- A contrast agent can be used to enhance image fidelity when necessary.

DISCUSSION

The present study demonstrates the feasibility of tablet-based limited cardiac ultrasound for the evaluation of patients with suspected or confirmed severe acute respiratory syndrome coronavirus-2 infection during the COVID-19 pandemic. The study provides the blueprint for an alternative work flow during the pandemic, or any other circumstance in which study time or operator risk is an important factor. Our approach reduces scan time and simplifies device decontamination without sacrificing the ability to obtain the information necessary for the clinician to make critical decisions.

Point-of-care focused cardiac ultrasound using a handheld device has been widely adopted as a diagnostic tool in critical care settings, including the intensive care unit and emergency department. In emergency department patients with hypotension of unclear etiology, point-of-care ultrasound provided useful diagnostic information within 6 min on average.[8] For patients with COVID-19, however, the advantage speed provides is an increase in operator safety. The portability, simplified features, and easy decontamination of a handheld ultrasound system provide an ideal alternative for imaging these highly contagious patients.

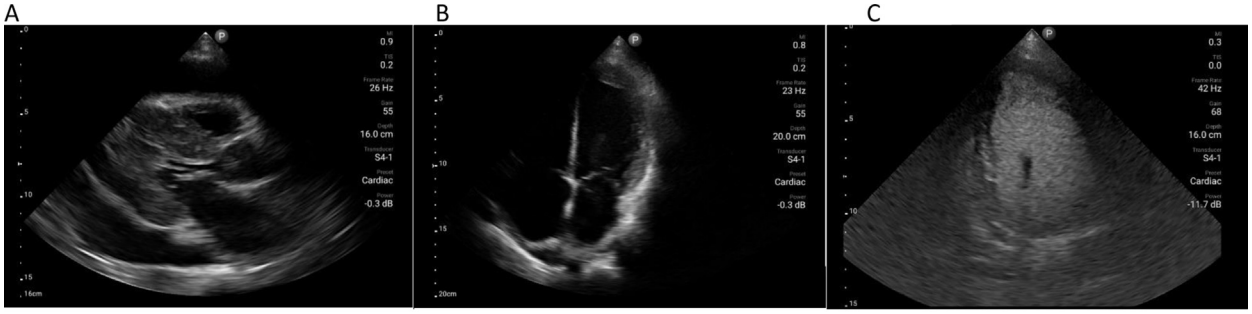
Our limited examination focused on biventricular size, function, wall motion assessment, pericardial effusion, brief assessment of valve function, and right atrial pressure. Similar protocols specific to patients with COVID-19 have been suggested in recent publications, with the additional emphasis upon diligently screening for appropriateness.[9,10] Our approach serves as a "gatekeeper" to the use of comprehensive echocardiography performed on full ultrasound platforms. A prior study demonstrated the feasibility using handheld echocardiography as a screening tool for appropriateness.[11] The present study validates the use of a preliminary limited assessment with a handheld ultrasound device in inpatients meeting appropriate use criteria in the COVID-19 population.

Severe cases of COVID-19 have been associated with greater viral load and longer duration of viral shedding.[12] Inpatients with COVID-19 may present a particularly high risk for disease transmission. Thus, mitigating risk by reducing exposure time is essential. In our study, the duration of scanning time for patients undergoing limited echocardiography was reduced by 79%. Furthermore, the total duration of time spent in the patient's room decreased by 71%. The ease of use, rapid image acquisition, and absence of plug-in, startup, and powering-down time all contribute to this significant reduction in exposure. Additionally, following the manufacturer-recommended protocol, the time required for disinfection decreased by 86% using a tablet sonograph.

In our cohort, only 12 patients (13%) undergoing tablet-based sonography required repeat imaging. The repeat studies were clinically appropriate reassessments in the setting of critical illness. No studies were repeated because of inadequate imaging or interpretation of the preliminary study performed on the tablet. There was no significant difference in number of repeat echocardiographic examinations between the limited tablet cohort and the control group.

The efficacy of our protocol has produced immediate benefits. To date, the laboratory has performed one comprehensive echocardiographic examination using a traditional platform on a patient with suspected COVID-19 as a primary study. The indication was cryptogenic stroke; the superior imaging of a full platform and the ability to perform and record a saline contrast injection provided better sensitivity for detection of suspected interatrial shunt.

The handheld system is best seen as an alternative and not a substitute for a comprehensive study. All three forms of resolution, axial, lateral, and temporal, are superior on a traditional platform compared with a handheld device. Focusing, harmonic imaging, compression, time-gain compensation, and strain imaging are all available on the former and not the latter. The comprehensive hemodynamic assessment spectral Doppler provides is absent. Given the ubiquitous presence of dyspnea in these patients, an assessment of pulmonary artery systolic pressure might be desired. However, in the unique circumstances produced by the pandemic, the advantages of the handheld device, it may be argued, thoroughly outweighed its limitations. Even the use of UEAs injected with the tablet set to reduced output power was possible when indicated (Figure 1). Tablet-based



Legend: PLAX = parasternal long axis, A4C = apical 4 chamber, UEA = ultrasound enhancing agent.

Figure 1 Tablet-based echocardiography on three patients with COVID-19. **(A)** Parasternal long-axis view with large pericardial effusion. **(B)** Apical four-chamber view demonstrating apical thrombus. **(C)** Apical four-chamber view with UEA **(C)**.

Table 2 Efficacy of handheld ultrasound in patients with COVID-19 compared with standard echocardiography

	Handheld echocardiography (*n* = 90)	Standard echocardiography (*n* = 90)	95% CI or χ^2	*P*
Age, y	67 ± 14	63 ± 15		.15
Sex, male	64	64	0	
BMI, kg/m^2	32 ± 10			
Adequate for indication	98	99		
Study time, min	5.4 ± 1.9	24 ± 6.8	−35 to −38	<.00001
WM interpreted	85	78	2.1	.34
MR interpreted	93	100	*	.012
PE interpreted	100	98	*	1.00
FU studies required (inadequately imaged)	0	0		
FU studies ordered for reevaluation	13	20	*	.77

BMI, Body mass indexed; *FU*, follow-up; *MR*, mitral regurgitation; *PE*, pericardial effusion; *WM*, wall motion.
Data are expressed as mean ± SD or as percentages.
*Fisher exact test.

ultrasound proved sufficient to guide pericardiocentesis in the catheterization laboratory in a patient with suspected COVID-19 with cardiac tamponade. Furthermore, images are stored and are reviewable in our picture archiving and communication system in accordance with American Society of Echocardiography recommendations[13] and undergo billing as limited echocardiographic studies, allowing complete integration into the laboratory work flow.

Limitations

This was a single-center, retrospective study with a small sample size. Readers could not be blinded to study type during interpretation. During this pandemic, ordering of diagnostic testing for COVID-19-positive patients is likely done with more prudence out of concern for staff members. This may have led to fewer repeat echocardiographic studies in the COVID-19 population compared with the control group. In facilities without proper integration of handheld ultrasound equipment to a picture archiving and communication system, a similar protocol may not be feasible. In the absence of the urgency produced by the pandemic, we would have preferred to study more patients, collect more data, and perform a validation study comparing tablet-based and comprehensive echocardiograms obtained in the same patients.

CONCLUSION

Under the direction of the echocardiography laboratory, limited tablet-based ultrasound can be successfully used for screening of severe acute respiratory syndrome coronavirus-2–related cardiac conditions. A limited protocol performed with handheld ultrasound provides adequate diagnostic information of the major cardiac complications of COVID-19 while decreasing sonographer exposure and simplifying decontamination.

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