Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
ECHOCARDIOGRAPHY IN COVID-19 PATIENTS

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

Sean R. McMahon, MD, Garrett De Francis, BS, RDCS, Sara Schwartz, BS, RCS, William L. Duvall, MD, Bhaskar Arora, MD, and David I. Silverman, MD, FASE, Hartford, Connecticut

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/m²). 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 ± 6.8 min on a traditional platform to 5.4 ± 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, 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.

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...
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|                             |

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.
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 workflow 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. 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. 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. 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. 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).

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).
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 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 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.

**REFERENCES**
1. Ng K, Poon BH, Kiat Puar TH, Shan Quah JL, Loh WJ, Wong YJ, et al. COVID-19 and the risk to health care workers: a case report. Ann Intern Med 2020;172:766-7.
2. Prinz C, Voigt JU. Diagnostic accuracy of a hand-held ultrasound scanner in routine patients referred for echocardiography. J Am Soc Echocardiogr 2011;24:111-6.
3. Reant P, Dijos M, Arsac F, Mignot A, Cadenaule F, Aumiaux A, et al. Validation of a new bedside echoscopic heart examination resulting in an improvement in echo-lab workflow. Arch Cardiovasc Dis 2011;104:171-7.
4. Cardim N, Dalen H, Voigt JU, Ionescu A, Price S, Neskovic AN, et al. The use of handheld ultrasound devices: a position statement of the European Association of Cardiovascular Imaging (2018 update). Eur Heart J Cardiovasc Imaging 2019;20:245-52.
5. Picard MH, Weiner RB. Echocardiography in the time of COVID-19. J Am Soc Echocardiogr 2020;33:674-5.
6. Porter TR, Mulvagh SL, Abdelmonem SS, Becher H, Belicik JT, Bierig M, et al. Clinical applications of ultrasonic enhancing agents in echocardiography: 2018 American Society of Echocardiography guidelines update. J Am Soc Echocardiogr 2018;31:241-74.
7. Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, et al. Guidelines for performing a comprehensive transthoracic echocardiographic examination in adults: recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2019;32:1-64.
8. Jones AE, Tayal VS, Sullivan DM, Kline JA. Randomized, controlled trial of immediate versus delayed goal directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. Crit Care Med 2004;32:1703-8.
9. John AM, Galen B, Kirkpatrick JN, Lanspa M, Mulvagh S, Thamman R. ASE statement on point-of-care ultrasound (POCUS) during the 2019 novel coronavirus pandemic. J Am Soc Echocardiogr 2020;33:670-3.
10. Ward RP, Lee L, Ward TJ, Lang RM. Utilization and appropriateness of transthoracic echocardiography in response to the COVID-19 pandemic. J Am Soc Echocardiogr 2020;33:690-1.

|                | Handheld echocardiography (n = 90) | Standard echocardiography (n = 90) | 95% CI or χ² | P     |
|----------------|------------------------------------|-----------------------------------|--------------|-------|
| Age, y         | 67 ± 14                            | 63 ± 15                           | .15          |
| Sex, male      | 64                                 | 64                                | 0            |
| BMI, kg/m²     | 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.
11. Haji K, Wong C, Neil C, Cox N, Mulligan A, Wright L, et al. Handheld ultrasound to reduce requests for inappropriate echocardiogram (HURRIE). Echo Res Pract 2019;6:91-6.

12. Liu Y, Yan LM, Wan L, Xiang TX, Le A, Liu JM, et al. Viral dynamics in mild and severe cases of COVID-19. Lancet Infect Dis 2020;20:e656-7.

13. Kirkpatrick JN, Grimm R, Johri AM, Kimura BJ, Kort S, Labovitz AJ, et al. Recommendations for echocardiography laboratories participating in cardiac point of care cardiac ultrasound (POCUS) and critical care echocardiography training: report from the American Society of Echocardiography. J Am Soc Echocardiogr 2020;33:409-22.e4.