INTRODUCTION
While first identified in December 2019, coronavirus disease 2019 (COVID-19) was not officially declared a global pandemic by the World Health Organization (WHO) until March 11, 2020. Since that time, new cases have been recorded in over 200 countries and in every state in the United States. COVID-19 poses a unique set of challenges to the healthcare system due to its rapid spread, intensive resource utilization, and relatively high morbidity and mortality. Healthcare workers are at especially high risk of exposure given the viruses spread through close contact. Reported cardiac complications of COVID-19 include myocarditis, acute coronary syndrome, cardiomyopathy, pericardial effusion, arrhythmia, and shock. Thus, echocardiography is integral in the timely diagnosis and clinical management of COVID-19 patients. Rush University Medical Center has been at the forefront of the COVID-19 response in Illinois with high numbers of cases reported in Chicago and surrounding areas. The echocardiography laboratory at Rush University Medical Center (RUMC) proactively took numerous steps to balance the imaging needs of a busy, nearly 700-bed academic medical center while maintaining safety.

LABORATORY CONSIDERATIONS
In the setting of a dynamic COVID-19 pandemic, the echocardiography laboratory must balance the duty of sonographers, nurses, advanced practice providers, and physicians to provide high-quality care while limiting viral spread, reducing staff exposure, and protecting cardiovascular disease patients. As always, all echocardiograms should be performed based on established appropriate use criteria.
FIGURE 1  Healthcare workers, and medical sonographers in particular, are at the greatest risk of COVID-19 due to daily exposure to the virus and work in close proximity to patients, based on data compiled by the United States Department of Labor.

FIGURE 2  Cardiologist, Dr Anupama Rao, MD, wearing full personal protective equipment including continuous air-purifying respirator (CAPR) prior to performing a TEE on a COVID + patient in the intensive care unit.
However, in response to the global pandemic, additional measures were enacted to screen and prioritize studies.

To preserve limited hospital resources and protect personnel, all nonurgent, elective outpatient noninvasive testing including transthoracic echocardiogram (TTE), transesophageal echocardiogram (TEE), and stress echocardiography studies were postponed beginning March 15, 2020. This decision predated Chicago’s closure of public schools by 2 days and the city’s stay at home order by 8 days. While these studies were initially rescheduled for 4 weeks, they are now postponed indefinitely until the COVID-19 hospital surges have been sufficiently mitigated. Urgent outpatient studies, such as prechemotherapy initiation or presurgery, are scheduled on an individual basis after discussion between the ordering provider and the echocardiography attending of the day.

For inpatient examinations, study appropriateness, study urgency, and patient clinical status are assessed on a case-by-case basis. Sonographers are empowered to flag any orders requiring further investigation or discussion. Based on American Society of Echocardiography (ASE) recommendations, COVID-19 status is divided into three categories: negative/not suspected, person under investigation (PUI), and confirmed. TTEs ordered for PUI and confirmed cases prompt early involvement of the referring physician to discuss the clinical indication. In general, routine TTE on COVID-19-positive patients are discouraged unless the results would significantly impact clinical management. When clinically appropriate, scans are deferred until test results came back negative (Supplement Fig S1).

Inpatient TEEs have also been screened in line with the ASE recommendations. TEEs are high-risk procedures given the capacity for viral aerosolization and/or direct droplet transmission of COVID-19 from both intubated and nonintubated patients. Infection risk applies to all members involved in the procedural team, including the cardiologist, cardiology fellow, echocardiographer, nurse, and anesthesia team. Consequently, nonessential TEEs have been deferred in lieu of alternative imaging modalities, or postponed. Clinically warranted studies are performed should the benefit of the TEE outweigh the risk of exposure and contamination from COVID-19. To date, only one TEE has been performed under anesthesia guidance for a COVID-19–positive patient with concomitant endocarditis. All personnel donned continuous airway purifying respirators (CAPR) during the entire TEE procedure, which was performed in an airborne precautions room (Figure 2).

At the time of the COVID-19 outbreak, Rush was piloting the use of point-of-care ultrasound (POCUS) by cardiology fellows and attendings on cardiology consult and intensive care services. POCUS is a particularly attractive modality in this circumstance as it limits exposure of equipment and personnel, can be completed quickly with focused views, and reduces the amount of personal protective equipment utilized. As a result, the pilot process was accelerated and all available handheld units were fully deployed to assist clinical decision making (Figure 3).

Indications for POCUS include significant troponin elevation, new cardiac abnormality on radiographic imaging, concern for shock, new heart failure, persistent arrhythmia, and/or significant ECG changes. If any new abnormalities are identified on POCUS, a sonographer-performed TTE is typically recommended.

### 3 | PROTECTIVE EQUIPMENT

Recommendations regarding the use of personal protective equipment (PPE) continue to evolve based on new evidence and supply constraints. The current Centers for Disease Control and Prevention (CDC) guidelines suggest the following PPE in a patient with known or suspected COVID-19: an N95 respirator or facemask, eye protection, gloves, and gowns. A recent study showed a high level of coronavirus on hospital floors (94%) and medical workers’ shoes (100%) in a Chinese hospital treating COVID-19 patients. Therefore, at RUMC, disposable shoe covers and bouffant caps are optional additions (Figure 3).

In addition to proper PPE, before entering a COVID-positive patient or PUI's room, it is paramount that a sonographer secures all the necessary equipment to safely complete the study. At RUMC, we utilize preassembled “COVID-Kits” contain one ultrasound probe cover, one panel cover, one 3 cc syringe for ultrasound enhancing agent (UEA) administration, two 10 cc flushes, and one ultrasound gel packet (Figure 4). A vial of ultrasound enhancing agent (UEA) is pulled from refrigerated storage and added to the kit before entering the room. UEAs are taken into every room given the high prevalence of suboptimal echocardiographic windows in COVID-positive patients, who are often intubated and in ICU settings. Prepackaged kits eliminate unnecessary egress from rooms and give the sonographer peace of mind in a stressful situation.

Finally, for all echocardiograms ordered on PUI and confirmed cases at RUMC, the performing sonographer is assigned a "buddy." The rationale for a “buddy system” is multifaceted. The TTE buddy helps ensure proper PPE use: checking that the mask and goggles have a good seal and that the gown is tied properly. While the...
sonographer performs the examination, the buddy waits outside the room to time the length of the study. The buddy facilitates doffing of PPE and handwashing, by removing the echo machine from the room at study completion. The PPE buddy is responsible for cleaning the machine outside of the room, thus minimizing the time spent by the sonographer in the room. In a highly stressful situation, the buddy also provides important emotional support. In the case of a TEE, extra precaution is applied when handling the TEE probe post-procedurally to minimize contamination. Together, these protocols prioritize the safety of sonographers and reduce viral contamination by emphasizing through cleaning of all equipment.

4 | LIMITED ECHOCARDIOGRAM PROTOCOL

Recognizing that prolonged exposure to COVID-19 increases the risk of viral transmission, at RUMC all echocardiograms, after appropriate screening, are defaulted to limited studies. When possible, the chart is reviewed to understand the clinical picture and the ordering physician is involved to ascertain the key questions that can be answered by TTE. In the majority of cases, left ventricular ejection fraction (LVEF), regional wall-motion abnormalities, right
ventricular function, and/or IVC assessment is requested. The abbreviated examinations attempt to balance a thorough evaluation of cardiac structure and function, while limiting contact.

The limited COVID TTE is comprised of 7 cardiac windows (Figure 5). The parasternal long-axis (PLAX) view is scanned at standard depth with and without color Doppler (CD) over the mitral valve (MV) and aortic valve (AV). Next, the parasternal short-axis view (PSAX) is examined at the basal, mid-, and apical views. CD is employed over the AV and tricuspid valve (TV) with the addition of continuous-wave Doppler (CWD) of the TV to assess right ventricular systolic pressure. At the apical four-chamber window, left ventricle (LV) and right ventricle (RV) focused views are taken for ejection fraction estimation. CD is performed over the MV and TV to assess for evidence of stenosis and/or regurgitation. Quickly rotating to the apical five-chamber view, CD is placed over the AV. CWD is measured over the LVOT and AV to assess stroke volume. Two-dimensional (2D) images are acquired in the apical three-chamber view with CD of the AV and MV. The apical two-chamber view is used for LVEF and left atrial size. CD can again be taken of the MV. Finally, the subcostal view is imaged to assess central venous pressure via the inferior vena cave (IVC) and to look for pericardial effusion. Motion mode (M-mode), diastolic function, and left ventricular strain are not routinely assessed.

The limited COVID TTE detailed above can be augmented at the discretion of the sonographer. For example, if there is valvular regurgitation or stenosis above moderate by CD, a full valve study is completed. Likewise, if there is a pericardial effusion with an engorged and blunted IVC, mitral and tricuspid inflow velocities will automatically be added. RUMC is fortunate to have extremely skilled sonographers who can be trusted to make diagnostic decisions on the fly. Furthermore, sonographers are encouraged to have a low threshold to use UEAs to eliminate the need to return to a COVID positive room for additional images. All TTE measurements are made after study completion, outside the patient’s room, to limit potential exposure.

Transesophageal echocardiogram studies are also focused to limit personnel exposure time, while adequately providing pertinent information to answer the clinical question.

5 | SCAN TIMES

To further ensure sonographer safety, TTE scan times are measured for each study and tracked longitudinally for each sonographer. With these data, an individual’s length of exposure can be accurately tracked and scanning time can be adjusted to ensure equity. This step is especially important for higher risk individuals, such as those with preexisting conditions, pregnancy, or age >60. Since implementation, the average scan duration has decreased 28% (Figure 6).

6 | CONCLUSION

A successful echocardiography laboratory must provide high-quality, timely, and clinically relevant cardiovascular imaging regardless of the circumstances. However, the COVID-19 pandemic has also highlighted the importance of implementing policies and procedures that prioritize the safety of sonographers and all echo laboratory personnel without diminishing quality. At RUMC, several important steps included postponing elective procedures, expanding the role of POCUS, thoroughly vetting inpatient studies, properly protecting equipment and staff, encouraging teamwork, limiting exposure by adjusting study parameters, and quantifying exposure to mitigate risk. Together, these initiatives will hopefully improve patient care and ensure staff well-being. At the time of publication, zero sonographers, cardiology attendings, or cardiology fellows have tested...
positive for COVID-19; only symptomatic employees have been tested in accordance with institutional policy. The scope of this article is limited to echo laboratory best practices during the pandemic. Future studies will evaluate the utility and use of performing limited TTEs and POCUS in patients with COVID-19, specifically in regard to adverse patient outcomes and correlation with biomarkers.

AUTHOR CONTRIBUTIONS
Alan Goldberg, MD, FACC, Stella Kyung, MD, Sean Swearingen, MD, and Anupama Rao, MD, FSCMR, contributed to conception/design of the study, critical revision of article, and approval of article.

ORCID
Alan B. Goldberg https://orcid.org/0000-0003-2257-119X

REFERENCES
1. WHO Timeline - COVID-19 [Internet]. [cited 2020 Apr 14]. https://www.who.int/news-room/detail/08-04-2020-who-timeline---covid-19
2. Coronavirus (COVID-19) - Google News [Internet]. [cited 2020 Apr 14]. https://news.google.com/covid19/map?hl=en-US&gl=US&ceid=US:en
3. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395(10223):507–513.
4. The workers who face the greatest coronavirus risk - The New York Times [Internet]. [cited 2020 Apr 14]. https://www.nytimes.com/interactive/2020/03/15/business/economy/coronavirus-s-worker-risk.html?auth=linked-google1tap&fbclid=IwAR0XRxEUCa0RBksEVlnrPHnvqv172QXx-7pgCKUp5lgYYjgNLgDEZ5saen&gclid=fb-share
5. Clerkin KJ, Fried JA, Raikhelkar J, et al. Coronavirus disease 2019 (COVID-19) and cardiovascular disease. Circulation. 2020;141(20):1648–1655.
6. COVID-19 [Internet]. [cited 2020 Apr 14]. https://covid19.healthdata.org/united-states-of-america/illinois
7. ASE statement on protection of patients and echocardiography service providers during the 2019 novel coronavirus outbreak. 2020.
8. Specific considerations for the protection of patients and echocardiography service providers when performing perioperative or periprocedural transesophageal echocardiography during the 2019 novel coronavirus outbreak: council on perioperative echocardiography supplement to the statement of the American society of echocardiography. 2020.
9. Kirkpatrick JN, Grimm R, Johri AM, 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(4):409–422.e4.
10. Cardiology - COVID-19 protocols [Internet]. [cited 2020 Apr 14]. https://covidprotocols.org/protocols/06-cardiology
11. Infection Control: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) | CDC [Internet]. [cited 2020 Apr 14]. https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html#adhere
12. Guo ZD, Wang ZY, Zhang SF, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. Emerg Infect Dis. 2020;26(7). https://doi.org/10.3201/eid2607.200885. [Epub ahead of print].

SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.

Fig S1. Protocol and precautions utilized for minimizing the risk from COVID19

How to cite this article: Goldberg AB, Kyung S, Swearingen S, Rao A. Expecting the unexpected: Echo laboratory preparedness in the time of COVID-19. Echocardiography. 2020;37:1272–1277. https://doi.org/10.1111/echo.14763