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## Innovative Transthoracic Echocardiographic Imaging on Prone Ventilated Patients With COVID-19 Using a Transesophageal Probe

Coronavirus disease-2019 (COVID-19) is causing severe pneumonia leading to acute respiratory distress syndrome, a condition where prone ventilation for >12 h/day has proven beneficial (1). Transthoracic echocardiography (TTE) to assess COVID-19-related cardiac complications (2) is very challenging for patients in the prone position. The aim of this study was to examine the feasibility of an innovative use of a transesophageal echocardiography (TEE) probe to perform TTEs in patients with COVID-19 who were invasively ventilated in the prone position.

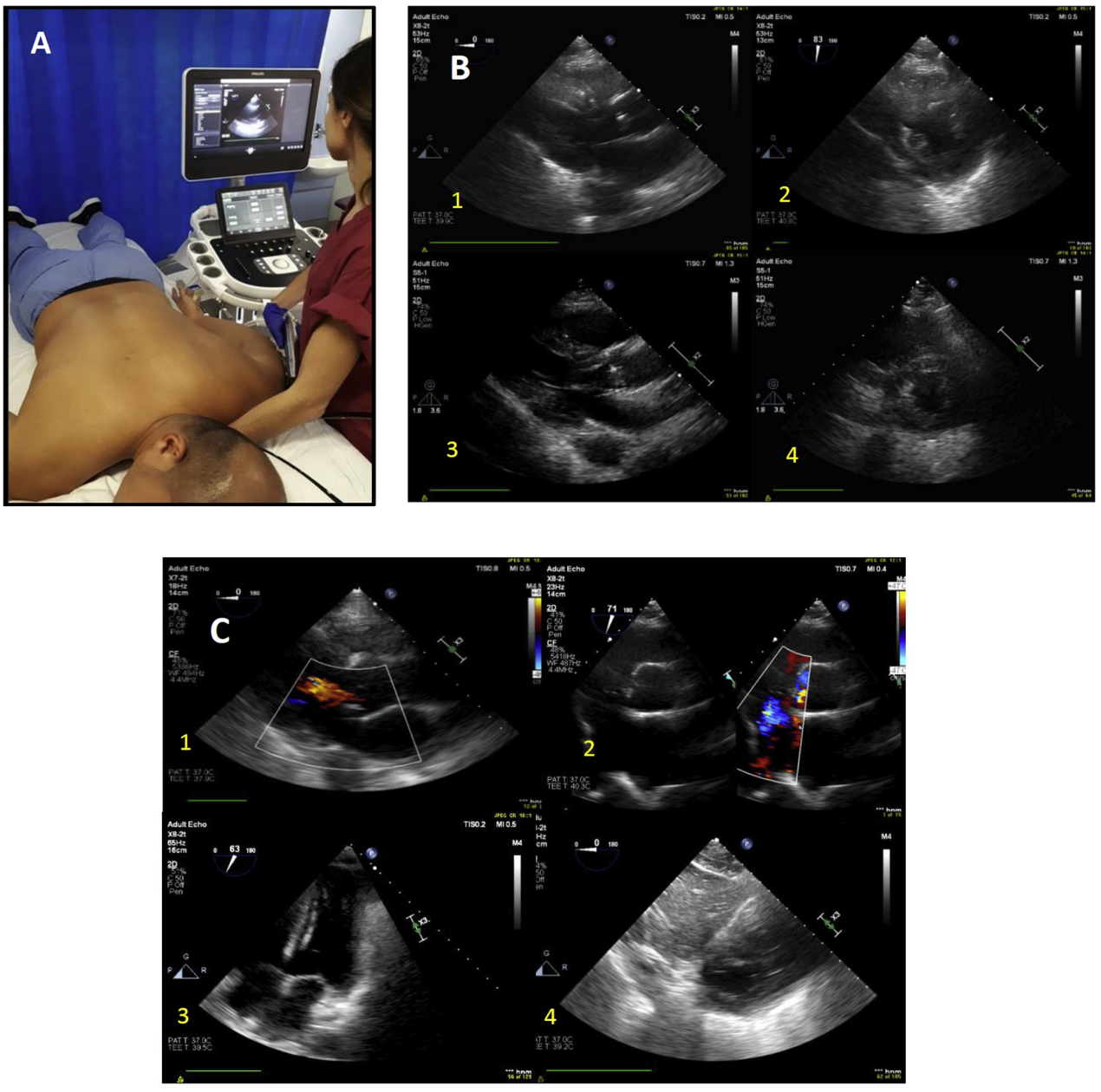
Twenty-one patients were examined. All scans were performed using an Affiniti or CVx system and the X7-2t or X8-2t TEE probes (Philips Healthcare, Andover, Massachusetts). In a small number of patients, several frequencies and harmonics were tested. The low fundamental frequency ("Pen" selection: 2.4 MHz) was found to provide the best image quality as visually assessed by 2 operators. The average duration of a scan with the TEE probe was 16 ± 3 min. In 18 of 21 patients (85.7%), conventional TTEs were performed using the same ultrasound machines and the S5-1 TTE probe (Philips) with the patients in the supine position. For those scans, the operators selected the frequency and harmonic functions based upon their discretion for optimal visualization (HGen: 1.6/3.2 MHz or HPen: 1.3/2.6 MHz). The studies were performed as part of routine clinical assessment or under ethical approval granted by the National Health Service Health Research Authority (REC20/EE/0131). The mean time between the 2 examinations was 3.6 days (range 0 to 12 days) and the order of the scans in each patient was random.

In order to acquire transthoracic images with the TEE probe, the operator stood on the left side of the patient at the level of their head, facing the patient's right side and caudally (**Figure 1A**). The probe was slid between the bed mattress and the patient's chest wall. Ultrasound gel was applied to the transducer surface. The direction of the probe was oblique from the patient's shoulder toward the mid-sternum. The transducer faced upward and was supported underneath by the operator's left hand. The probe shaft was held with the right hand to allow rotation, and the machine was operated by another operator. The tip of the probe was placed in the conventional left parasternal position, in the third or fourth left intercostal space. Images of the long axis of the heart were obtained at zero angle as in the conventional TTE parasternal long-axis view (**Figure 1B**). By increasing the angle to 60-120 degrees, a short axis view of the heart could be obtained, usually at the level of the mitral valve. Rotating the probe clockwise, the mid-papillary level and apical short axis views were obtained (**Figure 1B**), whereas with counterclockwise rotation, the great arteries were imaged. The application of color Doppler and pulsed and/or continuous wave Doppler allowed assessment of flow (**Figure 1C**).

The majority of patients were male (81%) and 48% were black. The mean age of the cohort was 55.9 ± 7.7 years, and the mean body mass index was 28.0 ± 4.6 kg/m$^2$. Three patients (14.3%) had a history of coronary artery disease, 5 (23.8%) were diabetic, 3 (14.3%) were smokers, and 4 (19.1%) had a history of lung disease.

The TEE and TTE probe echocardiograms were reviewed and interpreted independently by 2 blinded readers, and the image quality was graded as poor, fair, or good, by using criteria previously described (3). From the TEE probe scans, 4 were graded as nondiagnostic (19.0%), 5 were poor (23.8%), 1 was fair (4.8%), and 11 were good (52.4 %). From the 4 echocardiograms performed using the TEE probe, which were nondiagnostic, 2 correlated to poor conventional TTE image quality (both on female patients), and in the other 2, the conventional TTE was also nondiagnostic (both on male patients). The poor quality TEE probe scans corresponded to 3 poor and 1 good quality TTE probe scans (in 1 patient, a TTE probe scan was not available). The fair quality TEE probe scan corresponded to a fair quality TTE scan, and the 11 good quality TEE probe scans correlated to 1 fair and 8 good quality TTE probe scans (in 2 patients, TTE probe scans were not available).

**FIGURE 1** Demonstration of the Technique




**(A)** Demonstration of the technique. **(B) (1,2)** parasternal long axis (PLAX) and short axis (PSAX) views with the transesophageal echocardiography (TEE) probe. **(3,4)** PLAX and PSAX views with the transthoracic echocardiography probe. **(C)** TEE probe scans. **(1,2)** PLAX and PSAX views with color Doppler. **(3)** Apical 4-chamber view **(4)** subcostal short-axis view.

In 4 patients a D-shaped left ventricle and dilated right ventricle, compatible with right ventricular pressure overload, was found. In 1 patient, the left ventricular systolic function was found to be mildly impaired, and a small pericardial and pleural effusion were diagnosed in 2 patients. No valvular abnormalities were identified. The agreement between modalities in echocardiographic findings was 100%.

The technique described here has not been reported previously and, in 81% of patients, provided adequate image quality for basic left and right

ventricular assessment, valve function, and pericardial effusion. In 12 patients, it was possible to acquire apical views and in 4 a subcostal view was feasible (**Figure 1C**).

The unconventional and innovative use of a TEE probe to perform transthoracic echocardiography with the patient in prone positioned and invasively ventilated intensive care unit patients, is feasible and can be of diagnostic quality in most cases. The technique described here can be an alternative or even a superior to conventional TTE in prone patients.

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## Right Ventricular Function and Pulmonary Pressures as Independent Predictors of Survival in Patients With COVID-19 Pneumonia

Coronavirus disease-2019 (COVID-19) disease, caused by severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2), can lead to cardiac impairment, with increased troponin levels, left ventricular (LV) dysfunction and myocarditis (1,2). Information for right ventricular (RV) involvement and pulmonary pressures in these patients is limited, and this study aimed to explore the possible association between these factors and mortality. This study was conducted from February 20, 2020, to April 2020 in 4 centers. The final follow-up date was April 20, 2020. All consecutive patients with test results positive for SARS-CoV-2, as well as laboratory and computed tomography-confirmed interstitial pneumonia were included. Clinical, laboratory, radiological, and ultrasonographic data were collected. Cardiac injury was defined by measuring blood concentrations of high-sensitivity troponin I (hs-TnI) using the 99th percentile upper reference limit of the electrochemiluminescence immunoassay method. RV end-diastolic chamber size was assessed by using basal-tract and mid-tract diameters in apical 4-chamber view. Tricuspid annular plane systolic excursion (TAPSE) was calculated as a bedside-feasible index of RV longitudinal systolic function by aligning an M-mode cursor parallel with the RV free wall as it met the tricuspid annulus.

Pulmonary artery systolic pressure (PASP) was calculated by adding the value of right atrial pressure to the systolic transtricuspid gradient. Mean pulmonary artery pressure (mPAP) was calculated as $0.6 \times \text{PASP} + 2$ mm Hg (3). Outcomes of patients with cardiac involvement were compared to those in patients without cardiac involvement. An ethics committee approved the study, and all individuals gave written informed consent.

A total of 115 patients with COVID-19 pneumonia were included in the analysis. The mean age was 64.6 years (range 20 to 88 years of age), and 45 (40%) were female. Twenty-six patients had cardiac injury, and those patients were older (mean age: 73.5 years of age [range 37 to 88] vs. 55.3 years of age [range 20 to 78], respectively; $p < 0.001$). They also more frequently had systemic hypertension (16 of 26 patients [61.5%] vs. 26 of 89 patients [29.2%], respectively; $p < 0.001$). They also had higher levels of C-reactive protein (mean: 98.8 [range 45.8 to 130.4] $mg \cdot l^{-1}$ vs. 38.9 [range 22.2 to 96.3] $mg \cdot l^{-1}$, respectively; $p < 0.001$); higher D-Dimer (mean: 4.8 [3.2 to 7.1] vs. 2.1 [0.5 to 3.4], respectively; $p < 0.001$); a higher proportion of multiple ground-glass opacities in computed tomography (CT) findings (18 of 26 patients [69.2%] vs. 30 of 89 patients [33.7%], respectively; $p < 0.001$); and multiple consolidations by lung ultrasonography (20 of 26 patients [76.6%] vs. 34 of 89 patients [38.2%], respectively; $p < 0.001$). Lower-limb compression ultrasonography (CUS) was positive (proximal deep vein thrombosis of the common femoral vein and/or popliteal vein) only in 3 patients with cardiac injury and in 3 other patients without cardiac injury. A single echocardiograph for each hospital was identified,