Original Article

Transesophageal Echocardiography-Guided Extracorporeal Membrane Oxygenation Cannulation in COVID-19 Patients

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Objectives: A paucity of data supports the use of transesophageal echocardiography (TEE) for bedside extracorporeal membrane oxygenation (ECMO) cannulation. Concerns have been raised about performing TEEs in patients with COVID-19. The authors describe the use and safety of TEE guidance for ECMO cannulation for COVID-19.
Design: Single-center retrospective cohort study.
Setting: The study took place in the intensive care unit of an academic tertiary center.
Participants: The authors included 107 patients with confirmed SARS-CoV-2 infection who underwent bedside venovenous ECMO (VV ECMO) cannulation under TEE guidance between May 2020 and June 2021.
Interventions: TEE-guided bedside VV ECMO cannulation.
Measurements: Patient characteristics, physiologic and ventilatory parameters, and echocardiographic findings were analyzed. The primary outcome was the number of successful TEE-guided bedside cannulations without complications. The secondary outcomes were cannulation complications, frequency of cannula repositioning, and TEE-related complications.
Main Results: TEE-guided cannulation was successful in 99% of the patients. Initial cannula position was adequate in all but 1 patient. Fourteen patients (13%) required cannula repositioning during ECMO support. Forty-five patients (42%) had right ventricular systolic dysfunction, and 9 (8%) had left ventricular systolic dysfunction. Twelve patients (11%) had intracardiac thrombi. One superficial arterial injury and 1 pneumothorax occurred. No pericardial tamponade, hemothorax or intraabdominal bleeding occurred in the authors' cohort. No TEE-related complications or COVID-19 infection of healthcare providers were reported during this study.
Conclusions: Bedside TEE guidance for VV ECMO cannulation is safe in patients with severe respiratory failure due to COVID-19. No tamponade or hemothorax, nor TEE-related complications were observed in the authors' cohort.
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Key Words: COVID-19; transesophageal echocardiography; extracorporeal membrane oxygenation

Extracorporeal membrane oxygenation (ECMO) often represents the last resort option to maintain gas exchange in patients with refractory acute respiratory distress syndrome (ARDS), including for patients with COVID-19 pneumonia.[1-6] To date, the Extracorporeal Life Support Organization (ELSO) has reported the use of venovenous ECMO (VV ECMO) in

>14,000 confirmed COVID-19 patients, with in-hospital mortality of 47%.[5,7,8]

Correct positioning of the VV ECMO cannulae is crucial to achieving sufficient blood flow through the circuit while avoiding recirculation. The placement can be achieved using different techniques; these include anatomic landmarks, echocardiography, radiography, or fluoroscopy.[9-16] The use of imaging tools during ECMO cannulation may prevent severe complications, such as damage to major vessels or cardiac structures.[13,14] Although fluoroscopy may be used to ensure adequate ECMO cannula position, it has several disadvantages, including the need for intrahospital transport to a fluoroscopy suite, radiation use, and the inability to locate the exact position of the cannula's tip in relationship to cardiac chambers.[12,15,17-19]

In contrast, echocardiography allows clinicians to determine the cannula's exact position and diagnose potential procedure-related complications in real time. Echocardiographic guidance can be performed with either transthoracic (TTE) or transesophageal echocardiogram (TEE). Although TTE is readily available and noninvasive, it is most suitable for superficial structures, and its use may interfere with the sterile field. On the other hand, in mechanically ventilated adult patients, TEE allows for better visualization of the guidewires and cannula position without interfering with the sterile surgical procedure, thereby adding a layer of safety to the procedure.[12,13,20]

Currently, there is a paucity of data on the role of echocardiography for ECMO cannulation. Two literature reviews have reported the use of TEE in ECMO patients; one described the feasibility of using TEE to assess cannula position, and the other described the use of TEE in the intensive care unit (ICU) for the insertion of a dual-lumen bicaval cannula.[20,21] Furthermore, concerns have been raised about the safety of TEE in patients with COVID-19, as it may expose echocardiographers and other healthcare providers to the transmission of COVID-19.[22-25]

Before the onset of the COVID-19 pandemic, most patients requiring VV ECMO support in the authors' center were brought to the operating room (OR) and cannulated under fluoroscopy. This strategy was implemented after a series of major complications during cannulations with the landmark technique (Supplementary Appendix). However, during the pandemic, cannulation in the ICU was favored to limit the transfer of COVID-19 patients to the OR, and to reduce potential exposure of additional healthcare workers to the virus. A case of cardiac tamponade (post-ECMO cannulation using the landmark technique) prompted the authors to perform subsequent cannulations under TEE guidance. In the present work, the authors report their experience using TEE guidance for VV ECMO cannulations performed in the ICU for severe ARDS due to COVID-19. The authors investigated if TEE guidance for VV ECMO cannulation was feasible and safe in patients with COVID-19.

Methods

Study, Setting, and Patients' Characteristics

In this retrospective cohort study, the authors included patients with severe COVID-19-associated ARDS who were placed on VV ECMO support by the ECMO team of the Toronto General Hospital, an academic tertiary care center in Toronto, Canada. Decisions to initiate ECMO were made according to recently published ELSO guidelines.[6,26] The patients were included in the study if the cannulation was performed in the ICU under TEE guidance between May 2020 and June 2021, and they had COVID-19 infection confirmed by reverse transcription polymerase chain reaction test. Intraoperative cannulations and non-TEE-guided cannulations were excluded. Patients also were excluded if echocardiographic data were missing. This study was approved by the Institutional Research Ethics Board of the University Health Network.

Echocardiography Protocol

All TEEs were performed by an ICU attending physician certified in advanced perioperative TEE (National Board of Echocardiography). The TEEs were performed using the ICU ultrasound systems (Phillips), and echocardiographic images were stored on a dedicated data-sharing system (Syngo Dynamics). During the preparation for the procedure, the baseline TEE images were acquired to exclude any significant ventricular, valvular, or pericardial pathologies. Image acquisition and interpretation followed the American Society of Echocardiography (ASE) guidelines.[27-29]

For patients with ARDS, the authors' institution primarily used a femorojugular configuration, with a multistage cannula for drainage and a single-stage cannula for return. The ECMO cannulations were performed percutaneously using the Seldinger technique. Vascular access was performed under standard superficial ultrasound guidance. Insertion and positioning of the guidewires were conducted under real-time TEE guidance (Video 1). Particular attention was paid to ensure that the wires were not coiled in the right atrium (RA), through the tricuspid valve, or in the right ventricle (RV) (Video 2). Operators were guided to advance the wires while ensuring they were not abutting against cardiac chambers. When possible, the wires were positioned in both vena cavae, especially during sequential dilations and insertion of the cannulae (Fig. 1 and 2; Videos 3-4). The definitive position of the cannula tip was ascertained and deemed appropriate when the drainage cannula was above the inferior vena cava-right atrial (IVC-RA) junction (Fig 3; Video 5). The tip of the return cannula was placed a few centimeters above the superior vena cava-right atrial (SVC-RA) junction to ensure sufficient distance between the cannulae and reduce the risk of recirculation (Video 6). Reinfusion flow in the SVC and RA was ascertained using color-flow Doppler. Once the patient was repositioned in the semirecumbent position and after adjustments of the ventilatory settings, the echocardiographer verified that the drainage cannula was not against the interatrial septum (Video 7). When placing a dual-lumen bicaval cannula, particular attention was paid that the wire was inserted far into the IVC, beyond the take-off of the hepatic veins. It was ensured that the wire remained straight and in the IVC while the cannula was being
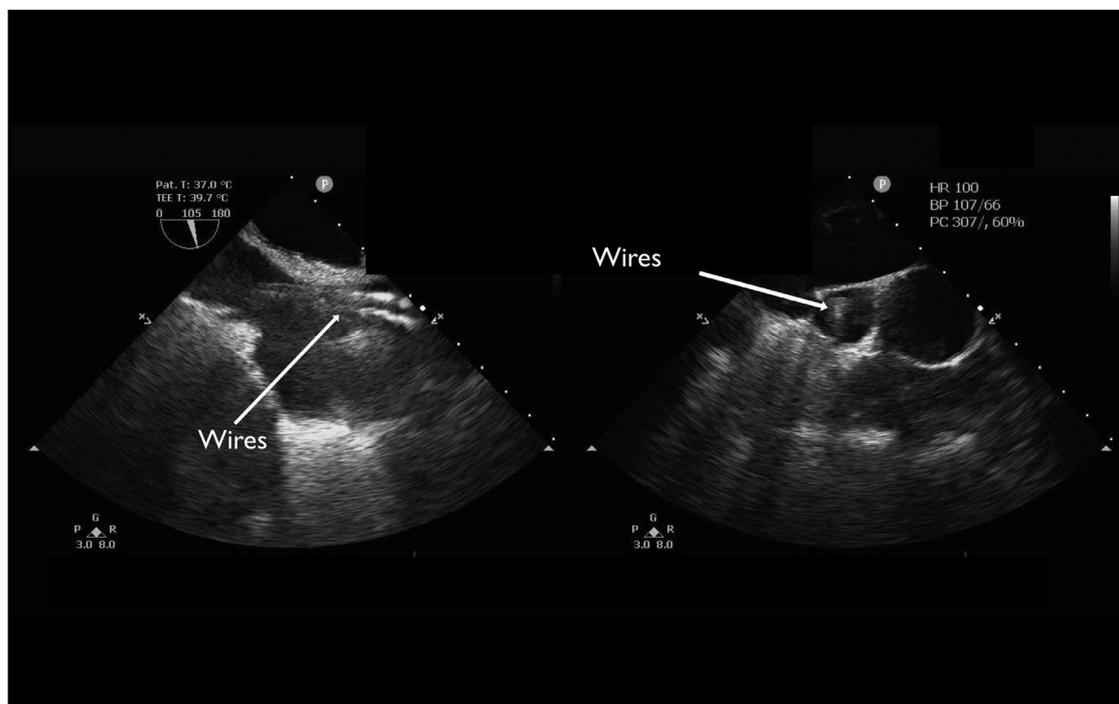
Fig 1. Midesophageal bicaval view with both wires in both vena cavae (*left*). Midesophageal short axis of the ascending aorta and superior vena cava with wires seen in the superior vena cava (*right*).
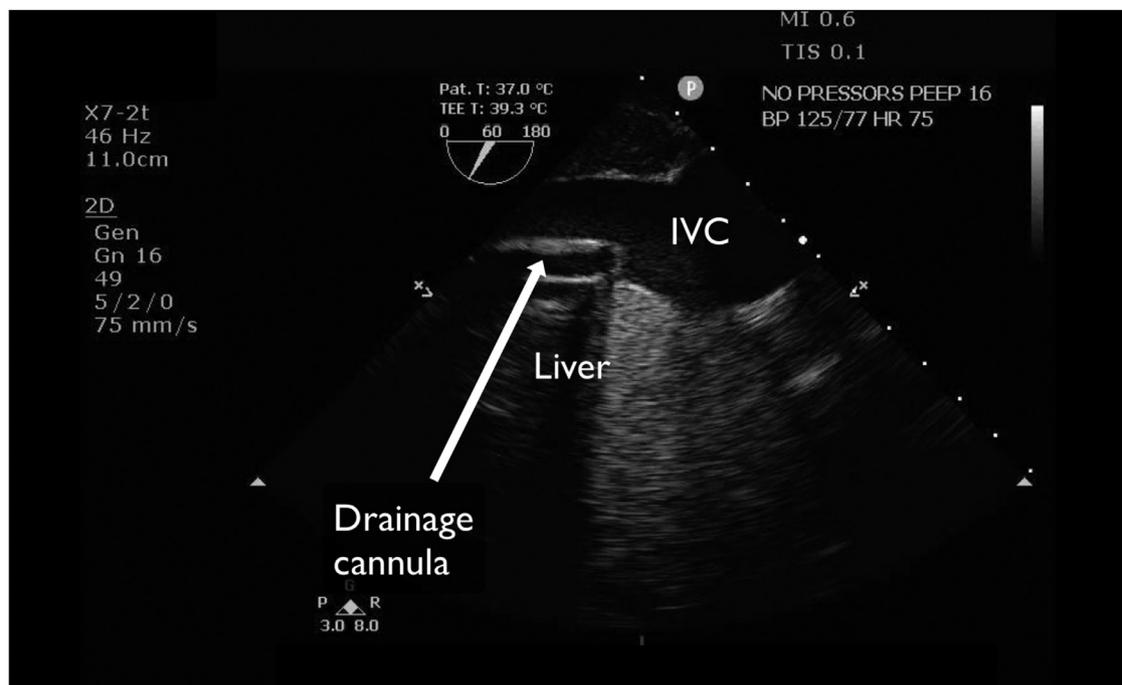
Fig 2. Transgastric view of the inferior vena cava showing the drainage cannula—inserted from the femoral vein—being advanced. IVC, inferior vena cava.

advanced. Once inserted, it was verified that the tip of the cannula was in the IVC (and not in a hepatic vein); color-flow Doppler was used to optimize the position of the return port within the right atrium so that the flow was directed toward the tricuspid valve.

At the end of the procedure, the echocardiographer ruled out the appearance of a new, or the increase in size of a preexisting, pericardial or pleural effusion.

Personnel Equipment and Protection

All personnel in the room wore personal protective equipment, including fit-tested N95 masks during cannulations as per institutional protocols, and a high-efficiency particulate air filter was used. The ultrasound systems were covered with colorless disposable bags, and the entire machine was disinfected upon completion of the procedure. In compliance with the authors'

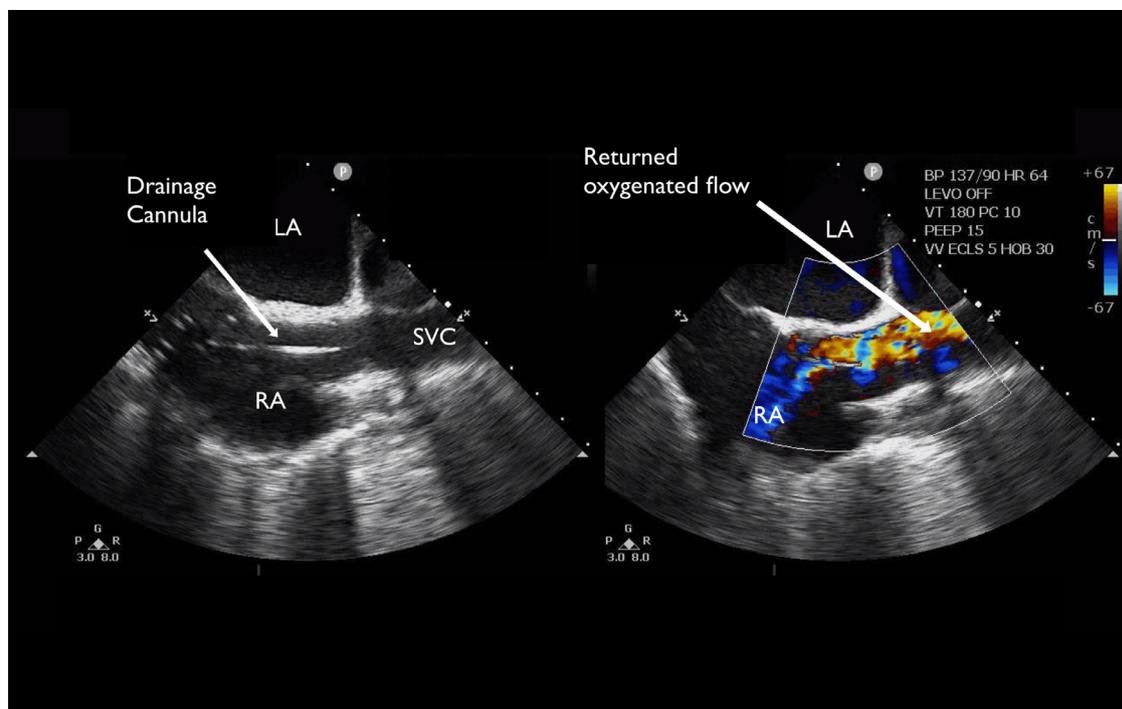Fig 3. Midesophageal bicaval view showing the tip of the drainage cannula in the right atrium just below the superior vena cava/right atrium junction (*left*). Midesophageal bicaval view with color-flow Doppler showing the returned oxygenated blood in the superior vena cava (*right*). LA, left atrium; RA, right atrium; SVC, superior vena cava.

institutional infection prevention control protocol, the authors did not use a cover for the TEE probe. The TEE probe was cleaned, placed in a closed container, and sterilized as per the authors' usual protocol.[22]

Variables and Outcomes

The authors' primary outcome was the number of successful TEE-guided cannulations without complications. Secondary outcomes were the number of cannulation complications, the number of patients requiring cannula repositioning during ECMO support, as well as the number of TEE-related complications. Major complications were defined as complications requiring intervention, such as a surgical, endoscopic, or radiologic procedure.[30] The TEE complications were defined as dental damage, oropharyngeal or upper gastrointestinal bleeding, esophageal perforation, or inadvertent extubation. The follow-up period for complications started with cannulation under TEE guidance and ended either at death or discharge from the authors' ICU.

Demographic data (age, sex), baseline characteristics (comorbidities), and pericannulation data (arterial blood gas and ventilatory parameters) were obtained from retrospective chart analysis. The patients' outcomes, such as mechanical ventilation duration, duration of ECMO support, hospital length of stay, and death, also were recorded. Two independent ICU echocardiographers reviewed the TEE images, and reports from the authors' local echocardiography system (Syngo Dynamics). Echocardiographic findings were analyzed based on the ASE recommendations.[27-29]

Analysis

When appropriate, the authors reported descriptive statistics using proportions for categorical variables, mean with standard deviation, and median with interquartile ranges for continuous variables. All analyses were conducted using Microsoft Excel.

Results

Patients' Demographics and Outcomes

During the study period, 126 patients were placed on VV ECMO for COVID-19 ARDS. A total of 109 patients underwent TEE-guided ECMO cannulation in the ICU, of whom 107 were included in the final analysis (Fig 4). Two patients were excluded due to missing echocardiographic data, as their echocardiographic images were not uploaded to the data-sharing system and were not available for review. The demographic and echocardiographic data, along with the main outcomes, are presented in Tables 1 and 2.

ECMO Cannulation and Complications

Overall, 106 patients were cannulated successfully in the ICU under TEE guidance without major complications. Five of these patients (5%) were cannulated by the authors' mobile ECMO team at the referring facility, as they were too unstable to be transferred safely without ECMO support. Most of the cannulations were intended to be femorojugular. One patient
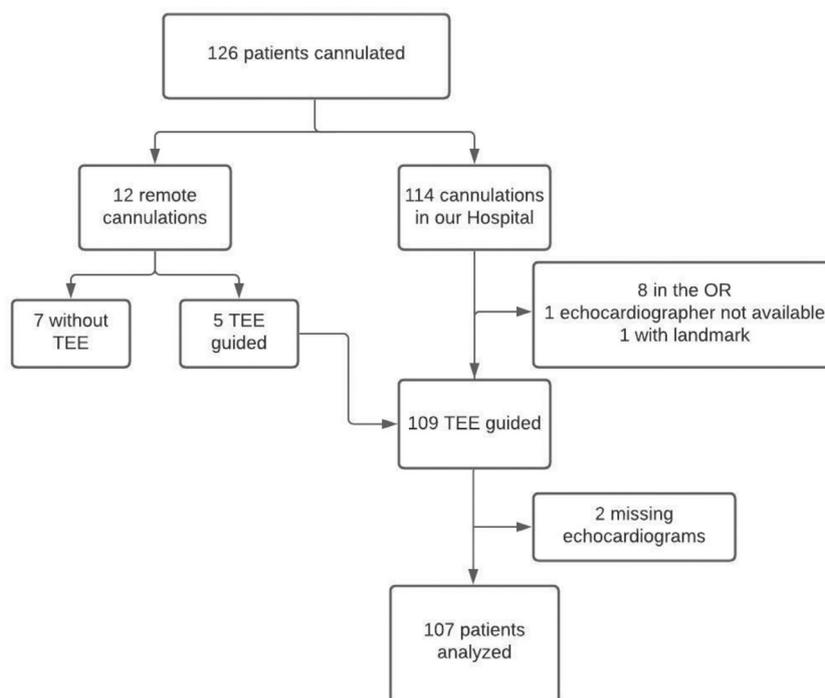
Fig 4. Flow diagram of venovenous extracorporeal membrane oxygenation cannulations performed during the COVID-19 pandemic. TEE, transesophageal echocardiography; OR, operating room.

Table 1
Patients' Characteristics at Time of ECMO Cannulation (N = 107)

Patients' Characteristics	
Age, y	49 (41-54)
Male sex	86 (80)
Comorbidities	
Hypertension	25 (24)
Diabetes mellitus	21 (18)
Respiratory disease	22 (20)
Cardiomyopathy	4 (4)
Renal disease	1 (1)
BMI (kg/m^2)	32.0 ± 8.3
Pre-ECMO parameters	
Arterial blood gas upon ECMO initiation	
pH	7.23 ± 0.1
PaCO$_2$, mmHg	73 (59-91)
PaO$_2$, mmHg	71 (64-88)
PaO$_2$/F$_I$O$_2$	74 (64-91)
Ventilation parameters	
Tidal volume, mL	323 ± 70
Tidal volume, mL/kg predicted body weight, median (IQR)	5.0 (4.4-5.8)
PEEP, cm H$_2$O	13 ± 4
Static driving pressure, cm H$_2$O	16 ± 4

NOTE. Data are expressed in mean ± standard deviation, median (IQR) or n (%).
Abbreviations: BMI, body mass index; ECMO, extracorporeal membrane oxygenation; F$_I$O$_2$, fraction of inspired oxygen; PaO$_2$, arterial partial pressure of oxygen; PaCO$_2$, arterial partial pressure of carbon dioxide; PEEP, positive end-expiratory pressure.

was cannulated with a dual-lumen bicaval cannula under TEE guidance, and one patient required conversion to a dual-lumen bicaval cannula after a failed attempt to dilate the femoral vein. One configuration was changed to femoro-femoral due to a thrombus visualized at the SVC-RA junction. One patient with severe RV dysfunction eventually required conversion to venoarteriovenous ECMO due to refractory shock.

One attempt to place a dual-lumen bicaval cannula under TEE guidance was unsuccessful. In this patient, the guidewire could not be advanced from the SVC to the IVC due to a prominent Eustachian valve causing the guidewire to repeatedly coil into the RV. A subsequent attempt of femorojugular cannulation was complicated by a femoral artery injury, for which the patient was transferred to the OR for surgical repair. The patient subsequently was cannulated in the OR under fluoroscopy, with a femorojugular configuration.

In addition to the previously described vascular injury, 1 pneumothorax (1%) was diagnosed with TEE during cannulation and confirmed with lung ultrasound and chest X-ray. The pneumothorax was managed conservatively. No cardiac injury or hemothorax occurred in the authors' cohort (Table 3).

Echocardiographic Findings and Complications

All patients had adequate acoustic windows. Echocardiographic findings are detailed in Table 4. In twelve patients (11%), echogenic structures suggestive of thrombi were visualized. Two (2%) were clots in transit, likely dislodged from a preexisting deep vein thrombosis upon insertion of ECMO wires; one (1%) was attached to the Eustachian valve, and one was the clot (mentioned above) at the SVC-RA junction. Eight patients (7%) had RV thrombi (Fig 5; Videos 9 and 10). A mobile mass suggestive of mitral valve vegetation with mild

Table 2
Patients' Outcomes (N = 107)

Mechanical ventilation duration, d	32 (18-52)
ECMO duration, d	29 (15-46)
	Median
Days to cannula reposition	11 (7-16)
Length of ICU stay, d	33 (19-54)
Death	
Total	57 (53)
On ECMO	52 (49)
In ICU (post-ECMO wean)	5 (4)

NOTE. Data are expressed in median (IQR) or n (%).
Abbreviations: ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit.

Table 3
ECMO and TEE-related Complications (N = 107)

ECMO cannulation complications	
Superficial vascular injury	1 (1)
Central vascular injury (IVC, SVC)	0 (0)
Hemothorax	0 (0)
Pneumothorax	1 (1)
Pericardial tamponade	0 (0)
TEE-related complications	
Dental injury	0 (0)
Diffuse oral bleeding	0 (0)
Upper GI bleeding	0 (0)
Esophageal perforation	0 (0)
Accidental extubation or endotracheal tube dislocation	0 (0)
Transmission of COVID-19 amongst echocardiographers	0 (0)

NOTE. Data are expressed in numbers, n (%).
Abbreviations: ECMO, extracorporeal membrane oxygenation; GI, gastrointestinal; IVC, inferior vena cava; SVC, superior vena cava; TEE, transesophageal echocardiography.

Table 4
Baseline and Intraprocedural TEE Findings (N = 107)

LV dysfunction[*]	9 (8)
Mild	7 (6)
Moderate	2 (2)
Hyperdynamic LV function with systolic anterior motion of the mitral valve	4 (4)
RV dilation	55 (51)
RV dysfunction	45 (42)
Mild	25 (23)
Moderate	11 (10)
Severe	9 (9)
Significant valvular pathology (more than mild)	8 (7)
Right ventricular thrombi	8 (7)
Right atrial thrombi	2 (2)
Thrombi in transit	2 (2)
Ventricular septal defect	2 (2)
Atrial septal defect with left-to-right shunting	1 (1)
Patent foramen ovale (color flow Doppler)	5 (5)
Pericardial effusion (at baseline)	11 (10)
Successful ECMO cannulation under TEE guidance[†]	106 (99)
Adequate cannula position[‡]	105 (99)

NOTE. Data are expressed in numbers, n (%).
Abbreviations: ARDS, acute respiratory distress syndrome; ECMO, extracorporeal membrane oxygenation; LV, left ventricle; RV, right ventricle; TEE, transesophageal echocardiography.
 [*] Cardiac chamber quantifications according to the American Society of Echocardiography.
 [†] One failed attempt of placement of a dual-lumen bicaval cannula for a recannulation for COVID-19 ARDS, with vascular injury requiring transfer to OR (operating room) for surgical repair.
 [‡] From the successful TEE-guided cannulations.

mitral regurgitation was present in one patient. Diastolic function was not fully assessed for all patients.

In 11 patients (10%), the wires were observed to be misplaced during the procedure, and repositioning was suggested. In 4 patients (4%), the wire was in one of the hepatic veins; in 4 patients (4%), it was inside the left atrium after crossing the fossa ovalis (Video 8); in 3 patients (3%), the wire was in the aorta, after going through the posterior wall of the internal jugular vein, thus prompting a new venipuncture. In one patient (1%), the wire initially was well-positioned in the SVC, but could no longer be visualized in the RA after one of the dilations. Upon removal of the wire, it appeared significantly bent. A new venous puncture and dilations were performed. No TEE-related complications were recorded in the authors' cohort (Table 4). Furthermore, no COVID-19 infections were diagnosed amongst echocardiographers during the study period.

Cannula Repositioning

Fourteen patients (13%) required cannula repositioning during ECMO support. One patient (1%) required immediate repositioning (<6 hours after ECMO insertion) due to cannula displacement with subsequent drop in ECMO flows and hypoxemia; 8 patients (7%) with femorojugular configuration required cannula repositioning due to inadequate flows later during ECMO support (median 11 days [7-16] after ECMO initiation). In these patients, the tip of the drainage cannula was seen within the IVC, below the IVC-RA junction; the cannula was further advanced into the RA, under echocardiographic guidance when feasible. By patient 30, 5 patients (17%) had required cannula repositioning for inadequate flows (including one patient with a dual-lumen bicaval cannula). For the first third of the cohort, the authors secured the drainage cannula at the IVC-RA junction (for femorojugular configuration); the authors subsequently modified their practice and secured the final position of the drainage cannula 2-to-3 cm above the IVC-RA junction, ensuring that its tip was not impinging against the interatrial septum (Video 5). After this modification, 5 (7%) of the remaining 75 patients (with 2 cannulation sites) required cannula repositioning for inadequate flows.

Both patients with dual-lumen bicaval cannulae required repositioning for persistent hypoxemia. In one patient, the drops in flows caused subsequent hypoxemia. The second patient became hypoxemic despite adequate flows. In this patient, the returned ECMO flow was no longer within the right atrium; instead, the returned oxygenated blood had become intrahepatic due to a significant elevation of the diaphragm secondary to loss in lung volumes (Videos 11 and 12). Lastly, 3 cannulae were repositioned due to accidental migration.
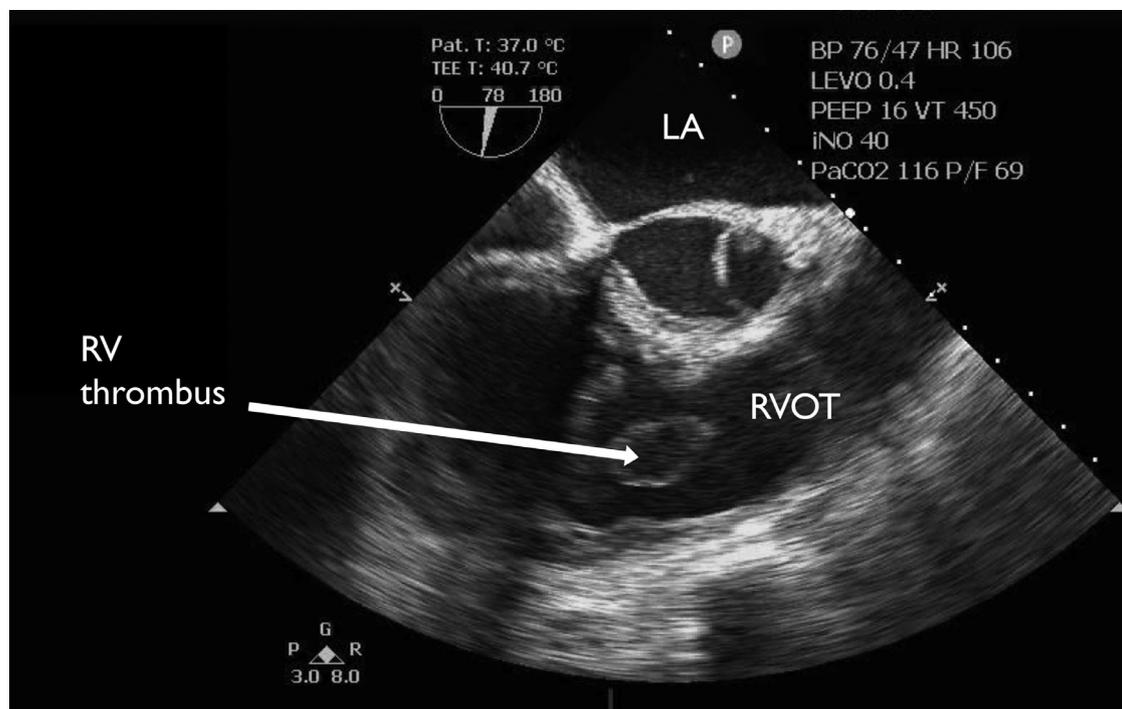
Fig 5. Modified midesophageal view of the right ventricle showing a right ventricular thrombus. LA, left atrium; RV, right ventricle; RVOT, right ventricular outflow tract.

Discussion

To the authors' knowledge, they reported the largest series of TEE-guided VV ECMO cannulations on patients with COVID-19 pneumonia. The TEE was feasible in all patients, and TEE-guided cannulation was successful in 99% of patients without major complications. The TEE guidance led to a change in the choice of ECMO configuration in one patient and intraprocedural modifications in 12 patients. Using TEE was safe for all patients and for the treatment team.

Previous work reported the occurrence of one vascular injury and one tamponade in a cohort of 179 patients cannulated under fluoroscopy guidance.[31] Other studies described using TEE for ECMO cannulation in smaller cohorts. Griffee et al. reported the use of TEE in 45 patients over a period of 6 years, and reported 2 cannulae mispositioned in the RV, one in the RA, and one SVC injury (with a new pericardial effusion).[21] Chimot et al. described a case series of 52 cannulations with dual-lumen bicaval cannulae (35 with TEE guidance and 13 with TTE; 2 with fluoroscopy guidance and 2 with the landmark technique).[32] They described one case of right atrial tear and one case of tricuspid valve lesion, but did not specify which imaging modality was used to guide these cannulations. To the authors' knowledge, the largest series studying complications of ECMO cannulation was from Rupprecht et al., who reported a 1.9% incidence of vascular injury requiring surgical revision. However, the authors did not mention the location of the cannulations or the type of guidance used.[33] In the present work, the authors found a similar complication rate; however, no pericardial effusion nor tamponade was recorded in the authors' patients.[34,35]

Indeed, the only procedural complications were a superficial arterial injury and a pneumothorax, which were not attributable to the use of TEE. Although there is still a risk of cardiac injury under TEE guidance, the authors' approach to ensure that both guidewires remained in both vena cavae without coiling in the heart may have added a substantial layer of safety to the procedure.

Adequate cannula position is crucial for VV ECMO functioning, because its malposition may result in loss of flow and recirculation, with subsequent hypoxemia, hemodynamic compromise, or injuries of major blood vessels or cardiac structures.[36] During cannulation, echocardiography identifies the exact position of both wires and cannulaes' tips.[13,17,20,37-39] Although TTE may be used for ECMO cannulation, it has a lower resolution, and acoustic windows may be inadequate in approximately 60% of patients, especially on mechanical ventilation.[17,22,37,40] Furthermore, even when adequate windows can be obtained, interference with the sterile field during ECMO cannulation remains a concern. As the authors' center did not have the capability to use fluoroscopy in the ICU, fluoroscopy guidance would have required a transfer to the OR or radiology suite. In addition, identification of the vessels and cardiac chambers may require administration of contrast, which is not innocuous in COVID-19 patients already prone to renal injuries. Finally, the protection of staff from potential harmful exposure during fluoroscopy represents a major limitation of fluoroscopy in the ICU. For these reasons, the authors chose TEE as their imaging modality. Although the authors did not compare patients cannulated under TEE guidance with those cannulated under fluoroscopy guidance, they emphasized that the ability to directly visualize the cannulae—during

patient repositioning and transition to a lung rest strategy—offers a significant advantage compared with other techniques.

Most TEE-associated complications reported in the literature arose from oropharyngeal trauma. Others included upper gastrointestinal hemorrhage, esophageal perforation, and inadvertent extubation. These complications occurred in 0 to 1% of the patients, with mortality rates between 0 and 0.1%.[20,41] The authors found that TEE guidance was feasible and safe in all patients, with no immediate complications.

Fourteen patients required cannula repositioning during their ECMO course despite adequate initial position. This incidence (13%) was lower than previous reports on dual-lumen bicaval cannula placement, showing that 38% of patients required echo-guided cannula adjustments.[21] Arguably, the need for late cannula reposition may be due to several factors unrelated to the initial position, such as cannula migration with the patient's positional changes, decrease in interstitial edema, or loss in lung volumes. Indeed, a lung rest strategy once the patient is on ECMO may lead to considerable reductions in lung volumes and diaphragmatic elevation, thus changing the cannula's position in relation to the atrio-caval junction.[42-44] Dual-lumen bicaval cannulae may be particularly affected by derecruitment and loss in lung volumes, as the return hole may become intrahepatic despite optimal position upon ECMO initiation.[13,45] Despite offering the advantage of a single cannulation site and easier mobilization, the authors' institutional practice has been to use dual-lumen bicaval cannulae for patients with less severe hypoxemia or predominant hypercapnic respiratory failure.

Despite concerns about using TEE for COVID-19 patients, guidance from the ASE describes its role and safety on intubated patients with COVID-19 ARDS.[22] Both TEE and cannulation are not traditionally considered aerosol-generating procedures when performed on intubated patients.[22,46,47] For safety reasons, the authors' team decided to wear full personal protective equipment (including N95) due to the duration of the procedure, possibility of accidental circuit disconnection, or extubation.[46,47] Although the authors' team members were not systematically tested, no transmission of COVID-19 was documented among the authors' team during the period studied. This was consistent with the report of Aviles-Jurado et al., who performed routine screening on operators performing percutaneous tracheostomies on COVID-19 patients.[48]

The limitations of this study included its retrospective nature and small sample size. It was also a single-center experience using descriptive data without comparison with other imaging modalities. Additionally, because cannulations primarily were performed in the OR before the pandemic, the authors could not compare their complication rate before and after the introduction of TEE guidance. Although the authors did not directly compare their complication rate to fluoroscopy-guided cannulations performed in the OR, TEE guidance proved to be equally, if not safer than cannulations with the landmark technique and cannulations performed in the OR. However, the authors' sample size may have limited the ability to observe rare complications. Additionally, most of the authors' patients were cannulated with a femoro-jugular configuration, which may not represent practices in other centers. Indeed, the authors only included 1 femoro-femoral configuration and 2 dual-lumen bicaval cannulae. Furthermore, in the authors' center, right atrium-pulmonary artery cannulae were placed in the OR under combined fluoroscopic and echocardiographic guidance, and were not included in their study.[49] Despite these limitations, this study represented the largest experience of TEE-guided ECMO cannulations on patients with COVID-19. Yet, for severe but rare complications, a larger population of patients undergoing VV ECMO would be needed to provide robust estimates of the risks.[21]

Conclusion

The safety of VV ECMO cannulation may be improved by using TEE guidance while avoiding the need for radiation, contrast, and transfer to the OR or radiology suites. Real-time guidewire visualization and optimal cannula placement prevent the most feared complications, such as cardiac and great vessel injuries. Moreover, TEE performed with appropriate personal protective equipment by certified echocardiographers is a safe procedure, even when performed on COVID-19 patients, as the authors did not encounter any TEE-related complications or COVID-19 transmission among their ECMO team. In conclusion, TEE should be considered a helpful tool for VV ECMO cannulation whenever feasible.

Acknowledgment

Conflict of Interest

Dr. Fan reports personal fees from ALung Technologies, Aerogen, Baxter, Boehringer-Ingelheim, GE Healthcare, Inspira, and Vasomune outside the submitted work. All other authors have disclosed that they do not have any conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2022.07.020.

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