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CHEST

Refractory Hypoxemia Despite Extracorporeal Membrane Oxygenation

Point-of-Care Ultrasound Is Needed for Patients With COVID-19

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A 42-year-old, previously healthy man presented to a community hospital with progressively worsening dyspnea and was diagnosed with acute hypoxemic respiratory failure requiring endotracheal intubation and mechanical ventilation. Over the subsequent days, the patient's PCR testing for severe acute respiratory syndrome-coronavirus 2 returned positive, confirming the diagnosis of coronavirus disease 2019 (COVID-19) pneumonia. Despite escalating mechanical ventilator support, the patient continued to deteriorate with worsening hypoxemia and hypercarbia (pH, 7.29; P_{CO_2}, 64 mm Hg; Pa_{O_2}/F_{IO_2}, 57; positive end-expiratory pressure, 18 cm H_2O). The decision was made to transfer the patient to our center for extracorporeal membrane oxygenation (ECMO).

Over the initial hours in our COVID-19 ICU, the patient underwent neuromuscular blockade and prone positioning ventilation; however, the patient continued to be hypoxemic. Given the progressive worsening of his respiratory status (pH, 7.25; P_{CO_2}, 71 mm Hg; Pa_{O_2}/F_{IO_2}, 73; positive end-expiratory pressure, 20 cm H_2O), the decision was made to transition him to venovenous extracorporeal membrane oxygenation (VV-ECMO) (respiratory ECMO survival prediction score, 3). The patient underwent right internal jugular vein cannulation, using a single-site, dual-lumen cannula (Avalon), for VV-ECMO. This was performed at the bedside under fluoroscopic guidance. The decision to perform this procedure at the bedside was driven by two factors: the emergency nature of the procedure and the desire to reduce the risk of contamination of catheterization laboratory equipment and staff exposure.

The next night the patient suddenly became bradycardic with progression to pulseless electrical activity, followed by wide-complex ventricular tachycardia. Advanced cardiac life support was initiated, with return of spontaneous circulation achieved after 2 min. After the return of spontaneous circulation, the patient continued to have transient bradyarrhythmias, worsening hypoxemia, and low-flow alarms on the Avalon catheter.

We performed a point-of-care ultrasound (POCUS) examination to evaluate the patient's etiology of cardiopulmonary failure (Videos 1-4).

Question: On the basis of the patient's history and POCUS evaluation, what is the most likely etiology of the patient's presentation?

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Answer: POCUS showed that the venous limb of the Avalon catheter no longer terminated in the inferior vena cava (IVC) and had shifted into the right atrium

Discussion

The differential diagnoses for hypoxemia during VV-ECMO include intrapulmonary shunt, new-onset cardiac failure, oxygenator dysfunction, high recirculation ratio, and catheter misplacement.[1-3] In the case of this patient, the most likely etiology of low-flow alarms and hypoxemia was Avalon catheter misplacement (Fig 1). Avalon catheters are indeed prone to dislodgement, causing life-threatening hypoxemia.[3] The most common mechanism of Avalon catheter dislodgement is insufficient depth inside the IVC at the time of initial placement, which leads to subsequent relocation of the outflow/reinfusion port at the level of the superior vena cava.[1,3] When inadequately inserted into the IVC, slight medial displacement of the catheter can redirect the distal tip of the catheter toward the right atrium.[3,4] Yet another mechanism of catheter displacement is its insertion into the hepatic vein, causing a reduction in ECMO circuit flows and higher negative venous pressures.[3,4] Last, a rotational displacement of the catheter will lead to misalignment of the outflow/reinfusion port and the tricuspid valve.[1] The ultimate consequence of all of these mechanisms is decreased efficacy of the VV-ECMO and worsening hypoxemia. Hence, the next logical step in evaluation of the patient was to confirm proper placement of the Avalon catheter.

We performed urgent transthoracic echocardiography (TTE), using a portable handheld ultrasound probe (Fig 2). Given its compact size and easy portability, it is our ultrasound of choice in patients with COVID-19 to help minimize equipment contamination. We did have our full TTE machine available as backup. Evaluation of the IVC on subcostal view confirmed that the Avalon catheter no longer terminated in the IVC (Video 1). The tip of the catheter was seen in the right atrium on subcostal four-chamber view as well as apical four-chamber views (Videos 2, 3). Furthermore, color flow Doppler assessment of the parasternal right ventricular inflow view confirmed that the outflow/reinfusion port no longer faced the tricuspid valve (Video 4, Discussion Video). Selective bedside TTE, using the portable ultrasound device, allowed for prompt diagnosis of Avalon catheter displacement as the cause of worsening hypoxemia and low-flow alarms. Subsequently, the patient underwent bedside repositioning of the Avalon catheter under TTE guidance.

A few cases of TTE-guided repositioning of the Avalon catheter have been described previously in the literature.[1,5,6] However, we believe ours to be the first report of diagnosing Avalon catheter displacement using a portable handheld ultrasound probe. The COVID-19

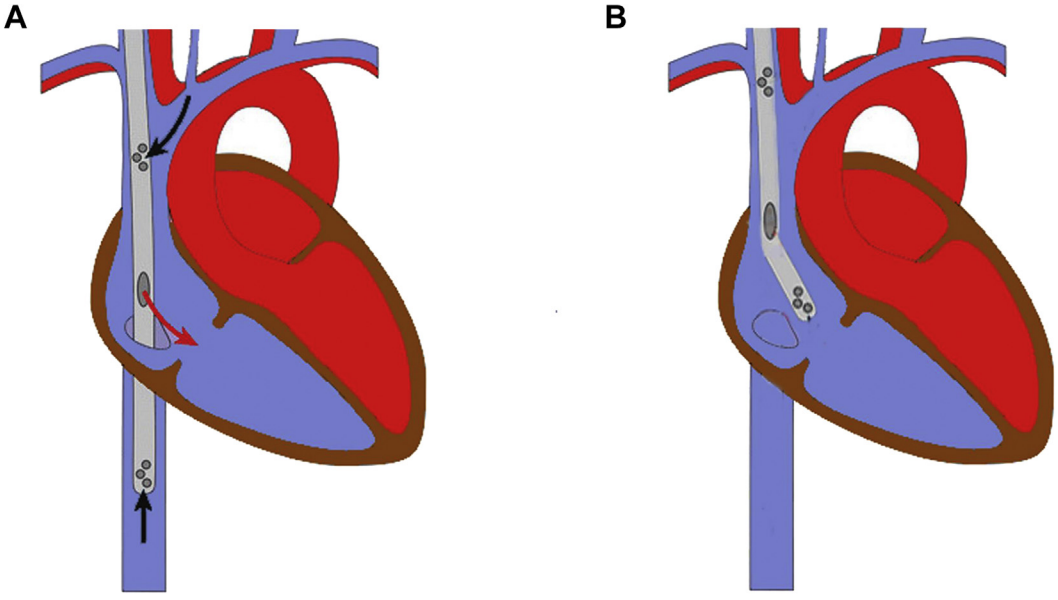

Figure 1 – *A, Avalon catheter correctly placed. B, Dislodged Avalon catheter.*

Figure 2 – *Handheld ultrasound connected to smartphone.*

pandemic has forced us to account for equipment contamination in deciding the most efficient diagnostic modality; a portable handheld ultrasound probe may be extremely useful as the entire probe and the screen interphase (tablet or phone) can fit into a regular ultrasound probe cover sleeve (Fig 3).

Chest radiography is another diagnostic modality that has been used to confirm the position of an Avalon catheter. Although it may raise suspicion of malposition or inadvertent migration, it is unable to confirm the exact position of the catheter as TTE is able to do.[1,3] Furthermore, TTE allows for repositioning of the catheter under direct visual anatomical guidance. Hence, an echocardiographic evaluation (TTE or transesophageal echocardiography) should be the preferred modality for confirmation of catheter position owing to its higher diagnostic accuracy.

Figure 3 – *A portable handheld ultrasound probe and smartphone interface sheathed in a standard ultrasound probe cover.*

Reverberations

1. *Catheter dislodgement is a potential cause of low flows and worsening hypoxemia during VV-ECMO, especially with the Avalon catheter.*
2. *Point-of-care TTE is an efficient and precise diagnostic modality in confirming positioning of the VV-ECMO catheter.*
3. *TTE should be the preferred diagnostic modality over chest radiography for evaluation of catheter positioning.*
4. *A portable handheld ultrasound probe may be useful for determining the positioning of ECMO catheters, and escalation to formal TTE/transesophageal echocardiography may be required if image acquisition is not optimal.*

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Additional information: To analyze this case with the videos, see the online article.

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