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Identification of Inadvertent Azygous Vein Cannulation Using Transthoracic Echocardiography During Venous Arterial Extracorporeal Membrane Oxygenation Initiation



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INTRODUCTION

It is well known that optimal cannula positioning during initiation of venous arterial (VA) extracorporeal membrane oxygenation (ECMO) is directly related to ECMO circuit function. Malpositioned cannulae can have deleterious effects on clinical outcomes, and inadvertent cannulation of the azygous vein during initiation of ECMO is a rare but potentially devastating complication that has been reported only a few times in the literature. Here we report a case of azygous vein cannulation in a neonate that was not identified on chest radiography but was recognized and corrected expeditiously with the use of transthoracic echocardiography.

CASE PRESENTATION

A full-term neonate was born without complications at an outside facility and subsequently became profoundly hypoxic within 30 min. At 20 hours of life, the infant was transferred to our facility for treatment of severe pulmonary hypertension and remained unresponsive to supplemental oxygen, inhaled nitric oxide, and high-frequency oscillatory ventilation, ultimately requiring VA ECMO support in the setting of impending cardiorespiratory collapse. A transverse right neck incision was made and, after adequate dissection and visualization of the vasculature, the neonate underwent cervical cannulation with placement of a 12-Fr venous Bio-Medicus (Medtronic, Minneapolis, MN) cannula in the right internal jugular vein and a 10-Fr arterial Bio-Medicus cannula in the right common carotid artery. An anteroposterior chest radiograph appeared to show the cannulae adequately positioned (Figure 1). ECMO flows were increased using a Sorin S5 (LivaNova, London, United Kingdom) roller head pump, but at 60 mL/kg/min of flow, the venous pressure became markedly negative, causing pump shutdown. Slight adjustments to the cannulae were made by the surgical team, and volume resuscitation was initiated with multiple 5% albumin boluses, but there was no improve-

ment in the ability to achieve adequate circulatory support. With the surgical team still scrubbed, transthoracic echocardiography was emergently performed under sterile conditions to evaluate for complications. Several subcostal sweeps performed in the sagittal plane revealed that the venous cannula was directed posteriorly (Figure 2) rather than inferiorly along the expected course through the superior vena cava (SVC) into the right atrium. Although consideration was given to the possibility of vascular perforation because of the location of the cannula tip, two-dimensional and color Doppler imaging demonstrated venous blood flow along a vascular structure consistent with the azygous vein, within which the cannula appeared to travel (Figure 3). The surgical team was able to manipulate the cannula during image acquisition to confirm its location for the cardiology team (Video 1). With this confirmation, the cannula was partially withdrawn and readvanced smoothly through the SVC into the right atrium under echocardiographic guidance. Subsequent views showed the distal tip of the venous cannula in an appropriate position within the right atrium (Figures 4 and 5), with immediate improvement in venous return. The cannulae were then sutured in place as the patient began to show marked improvement in oxygenation and cardiac output.

DISCUSSION

Initiation of VA ECMO in a critically ill patient requires knowledge of the vascular anatomy and proper positioning of the venous and arterial cannulae to achieve adequate venous drainage and arterial blood flow. During cervical ECMO cannulation, the venous cannula is commonly advanced through the right internal jugular vein into the SVC until the distal tip rests within the right atrium, unobstructed by the atrial septum and separated from the hepatic veins in order to achieve optimal systemic venous drainage. The arterial cannula is ideally advanced through the right common carotid artery until the distal tip reaches the aortic arch. Once flow is initiated, clinical data obtained from the circuit and the patient are helpful in determining if there is adequate cardiopulmonary support. At our institution, as well as others, anteroposterior chest radiography is routinely performed to verify cannula position before suturing the cannula in place. Echocardiography is typically performed as well but is often delayed until after the cannulae are secured and the neck wound is closed, making repositioning of the cannulae more complicated.

Verification of cannula position has traditionally been accomplished using chest radiography. In 1998 Irish *et al.*¹ reviewed the charts of 73 patients who had undergone cervical ECMO cannulation without confirmation of cannula placement by echocardiography and found that 18 of these patients (24.6%) ultimately required

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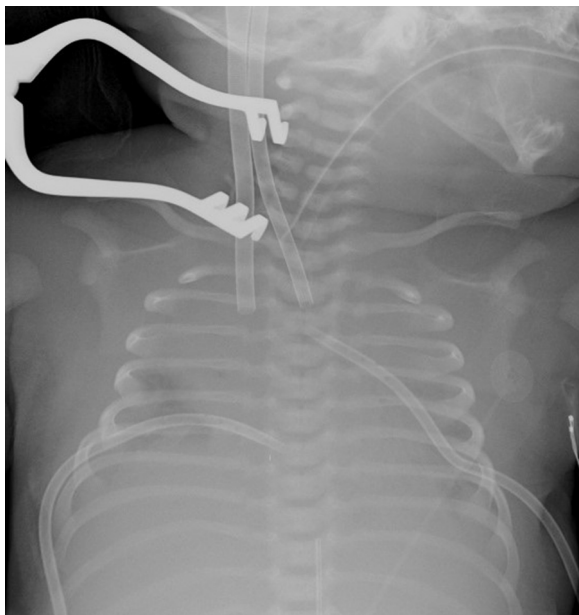


Figure 1 A chest radiograph taken immediately after cannula placement appears to show the arterial and venous cannula tips projecting over the region of the proximal SVC and aortic arch. Flows could not be achieved during initiation of ECMO, because of pump stoppage when 60 mL/kg/min of flow was reached.

repositioning of either the venous or arterial cannula. Importantly, cannula malposition was not detected on chest radiography in more than half of these patients, and a second cervical exploration was required for repositioning. They asserted that two-dimensional echocardiography may be a superior, cost-effective tool to verify cannula placement before wound closure. A similar conclusion was reached by Thomas *et al.*² in 2009 after a retrospective review of 100 patients requiring ECMO support revealed that 91 patients had undergone echocardiography while on ECMO, and 13% of those patients required intervention to address echocardiographic findings, with chest radiography failing to identify malpositioned cannulae in eight patients.

There are few reports of azygous vein cannulation in the literature, and all but one are described during cervical ECMO cannulation in neonates and infants. In 2007, Fisher *et al.*³ described two patients with right-sided congenital diaphragmatic hernia and inadvertent azygous vein cannulation. In both of these cases the complication was visualized by echocardiography and was postulated to result from azygous vein dilation secondary to compression of the inferior vena cava by a herniated liver. In one of the patients, autopsy confirmed this hypothesis. A second group from Korea described the same phenomenon in 2016.⁴ Byrnes *et al.*⁵ reported a case of a neonate in 2011 with prenatal closure of the ductus arteriosus whose azygous vein was cannulated and later identified and corrected using lateral chest radiography and two-dimensional echocardiographic guidance. Another case of inadvertent azygous cannulation that went undetected on chest radiography was described by Balmaks *et al.*⁶ in 2013. In this case, a 12-month-old with a history of chronic lung disease and ligation of a patent ductus arteriosus with elevated right heart pressures ultimately died <24 hours after ECMO initiation

and was found to have azygous cannulation at autopsy.⁶ There was clinical evidence of poor venous return, but no echocardiographic examination was performed in this case to evaluate cannula placement. In these cases the patients were noted to have the potential for elevated right atrial and SVC pressures that may have put them at higher risk for the venous cannula entering the azygous vein. Outside of the pediatric literature, we found a single case report of inadvertent azygous cannulation in an adult, in which a 39-year-old man with congestive heart failure had his azygous vein cannulated during initiation of cardiopulmonary bypass. The complication was identified with astute monitoring of a rising SVC pressure and was directly visualized by the cardiothoracic surgeon.⁷

In our patient there were immediate clinical signs of inadequate venous drainage despite an anteroposterior chest film that appeared to show satisfactory cannula placement. Our institution offers around-the-clock emergent echocardiographic services; thus, for this early-morning procedure, a sonographer and pediatric cardiology fellow were present at the bedside, with the staff cardiologist providing supervising interpretation from a remote location. With the surgical team still scrubbed and the wound draped, transthoracic echocardiography could be obtained rapidly in a sterile fashion, leading to a successful intervention. Similar to reports from others, our patient may have been at higher risk for azygous vein cannulation secondary to increased right atrial and SVC pressures. The patient had clinical signs of pulmonary hypertension upon presentation, and echocardiographic findings supported this diagnosis shortly before ECMO cannulation, with moderate right atrial enlargement, right-to-left flow across both a moderate-sized atrial septal defect and large patent ductus arteriosus, and flattening of the interventricular septum. Given this clinical scenario, having echocardiography readily available to guide cannulation was imperative. Our patient ultimately remained on ECMO support for 24 days with continued evidence of persistent pulmonary hypertension despite administration of pulmonary antihypertensive medications. The patient was ultimately extubated at about 5 weeks of age but demonstrated immediate respiratory instability, and the family elected to withdraw support at that time. An autopsy found the mechanism of death to be respiratory failure secondary to alveolar capillary dysplasia. There were no intracardiac or vascular abnormalities found during the autopsy.

CONCLUSION

Inadvertent cannulation of the azygous vein is rare and presents a diagnostic challenge during cervical ECMO cannulation. It can be easily missed with standard radiographic imaging, potentially leading to delays in initiation of adequate support and clinical deterioration of the patient. Echocardiography is a noninvasive, widely available, useful modality that can be used immediately at the bedside to assess and direct cannula positioning in real time during initiation of VA ECMO support. Given that image guidance is now the standard of care during most invasive procedures, echocardiography should be used routinely to guide cervical ECMO cannulation.

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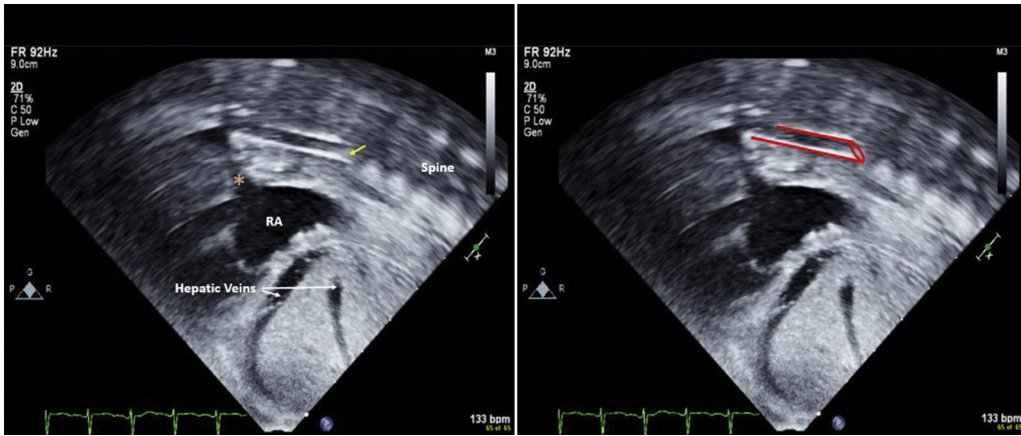


Figure 2 A subcostal sagittal view obtained during ECMO cannulation shows the venous cannula directed posteriorly into the azygous vein. The venous cannula tip (*yellow arrow*) can be seen directed posteriorly toward the spine. With appropriate positioning, the venous cannula should be seen coursing anteriorly into the SVC (*asterisk*), with the tip projecting into the right atrium (RA). Without evidence of venous blood flow into the cannula, the differential diagnosis for this positioning includes vascular perforation. In the accompanying image, the distal portion of the cannula is outlined in *red*.

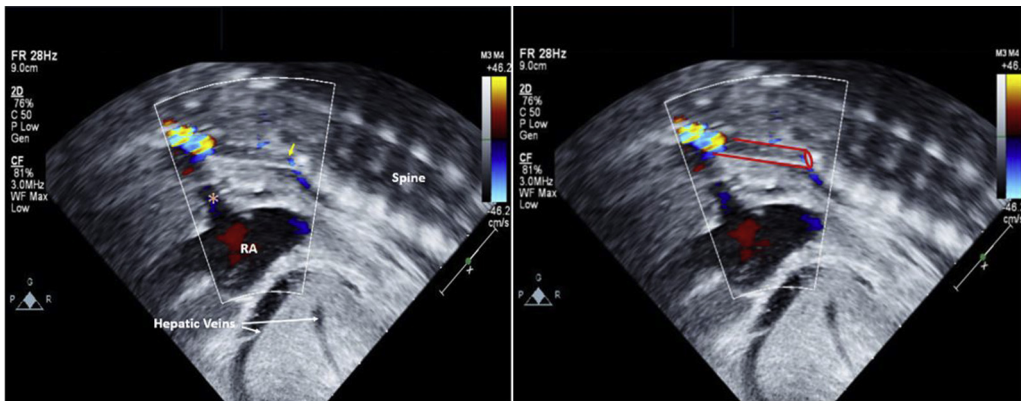


Figure 3 A subcostal sagittal view with color Doppler shows evidence of blood flow (*blue flow*) near the tip of the cannula (*yellow arrow*) in the distal portion of the vessel. It remains apparent that the cannula is not descending through the SVC (*asterisk*) into the right atrium (RA), as would be expected. In the accompanying image, the distal portion of the cannula is outlined in *red*.

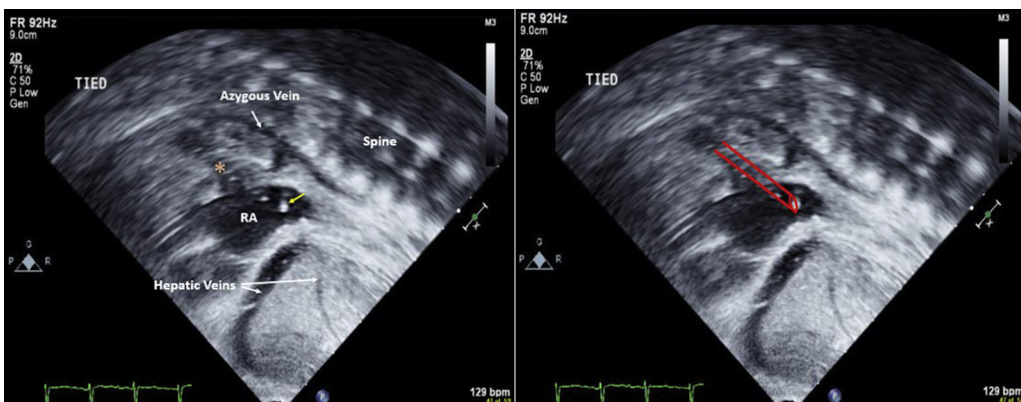


Figure 4 This subcostal sagittal view was obtained after the cannula was withdrawn from the azygous vein and readvanced into the SVC (*asterisk*). The venous cannula tip (*yellow arrow*) can be seen projecting into the lower right atrium (RA) through the SVC (*asterisk*), and the azygous vein is seen coursing along the anterior spine. The cannula was tied into position after significant improvement in ECMO flows. In the accompanying image, the distal portion of the cannula is outlined in *red*.

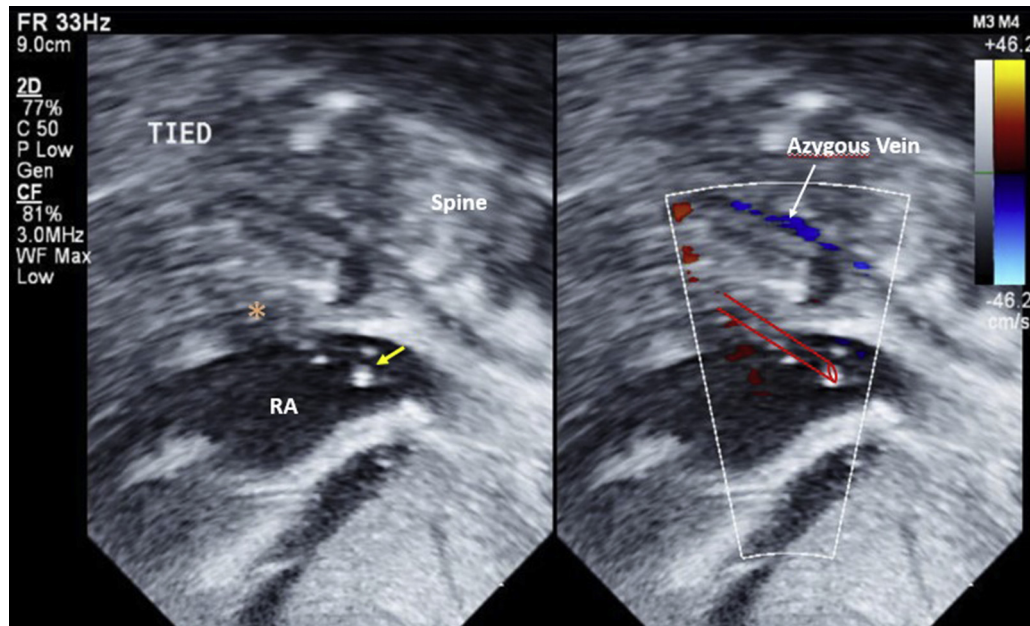


Figure 5 Color-compare imaging depicts a similar subcostal sagittal view that was obtained after repositioning of the tip of the venous cannula (*yellow arrow*) through the SVC (*asterisk*) into the right atrium (RA). The two-dimensional image is on the *left* with color overlaying the identical image on the *right* with the distal tip of the venous cannula outlined in *red*. Venous blood flow (*blue* flow away from the transducer) can be seen in the azygous vein, which is now unobstructed by the cannula. The infant had no clinical evidence of vascular perforation after successful repositioning of the cannula.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.case.2018.10.003>.

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