Malposition of Double Lumen Bicaval Venovenous Extracorporeal Membrane Oxygenation (VV ECMO) cannula resulting in hepatic venous congestion

Abstract

Introduction: Optimal positioning of double lumen bicaval canula for extracorporeal membrane oxygenation (ECMO) support used as a rescue measure in refractory hypoxaemia is essential to facilitate adequate oxygenation, prevent recirculation and avoid complications.

Method: Echocardiography via transoesophageal or transthoracic windows can be used as guidance and as a surveillance technique to prevent cannula malposition. We describe a case of Double-Lumen Bicaval VV ECMO cannula malposition leading to a massive retrograde hepatic venous flow.

Conclusion: Rapid echocardiographic diagnosis was pivotal in preventing potentially fatal complications.

Keywords: hepatic congestion, transthoracic echocardiography (TTE), venovenous extracorporeal membrane oxygenation.

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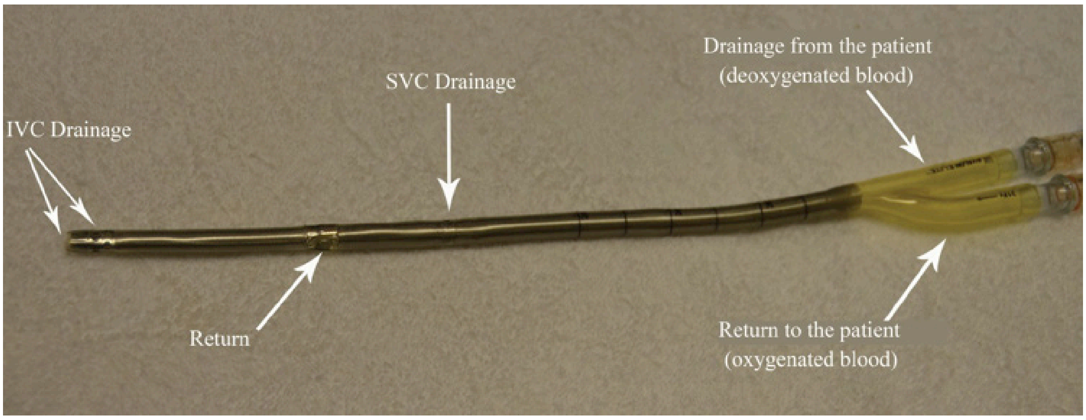

Figure 1: Avalon double lumen bicaval venovenous ECMO cannula.

Introduction

Modern intensive care management of acute severe refractory respiratory failure include the technique of veno-venous extracorporeal membrane oxygenation (VV-ECMO). The procedure provides extracorporeal blood circulation with blood drained from a large vein, oxygenated and then returned to a large vein. Oxygenation takes place during the contact of blood with oxygen via semi-permeable membrane (oxygenator) outside human body. To ensure adequate global oxygenation, extracorporeal blood flows are matched to the patient's native cardiac output, which can range between 4–6 L/min for an average adult.[1] Such flows can only be achieved with very large venous cannulas inserted percutaneously or surgically into central veins.

Recent developments in technology allowed to avoid placement of several separate cannulas and to provide adequate blood flows via single bicaval double-lumen cannula (Avalon Cannula, Avalon Laboratories, Rancho Dominguez, CA).[2,3] The device is available in several sizes with the largest being 31FG in diameter and in separate lengths up to 31 cm long internally when measured from the skin. Venous drainage is done using two ports which are connected into one lumen. There is a distal large port with a tip approximately 7 mm in diameter with 8 small side holes around the tip to avoid suctioning to the venous wall. The proximal drainage port has three holes which are approximately 3 mm in diameter. The distal and proximal ports are separated by approximate distance of 14.5 cm. The return of oxygenated

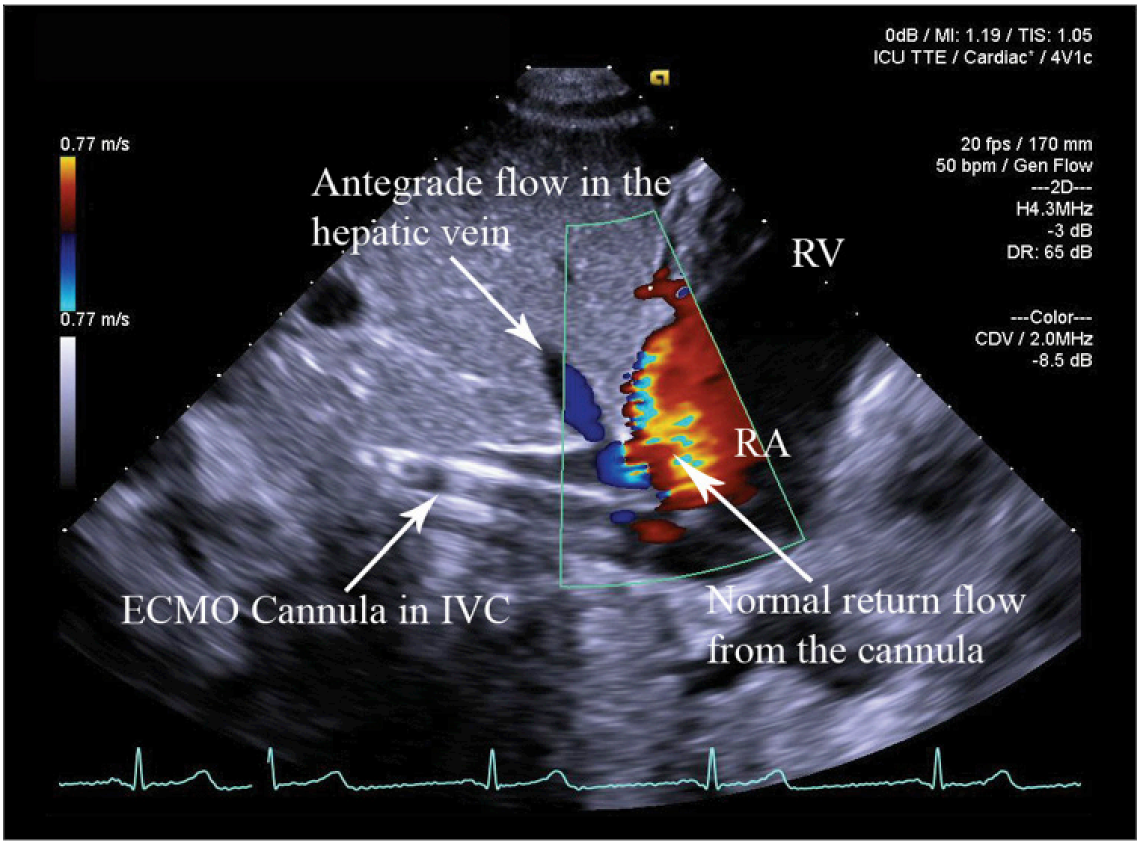

Figure 2: TTE: Subcostal window. Long-axis IVC plane. Color Doppler Mode. Normal antegrade flow in the hepatic vein and adequate right atrial return flow from VV ECMO cannula.

blood is done via the port connected to the second lumen, which is positioned between distal and proximal drainage ports and is about 9 cm from the tip of the cannula (Figure 1).

Technique

Positioning of bicaval double lumen catheter requires imaging – either dynamic X-rays or dynamic real-time echocardiography, or a combination of both.[3–5] The ideal position is achieved when the distal drainage port is located in inferior vena cava (IVC), immediately below the hepatic veins. The proximal drainage port needs to be located in a superior vena cava (SVC). The return port must be placed within right atrium and the return flow directed towards tricuspid valve. As a result, venous deoxygenated blood is drained from inferior and superior vena cava, and then, following extracorporeal oxygenation, blood is returned straight into the right heart avoiding recirculation.

Cannulation is normally done with access via the right internal jugular (RIJ) vein, which is ideally aligned with superior vena cava. Seldinger's technique is used after the puncture of RIJ vein. 0.038" 100 cm or 210 cm long J-wire is threaded via RIJ vein-SVC-RA-IVC under image guidance. Sequential dilation technique is then used prior to introducing the cannula. Once the position is deemed adequate, the cannula is connected to the extracorporeal circuit and the flow starts. Color Doppler is then used to fine-tune position of the return port with oxygenated blood flow expected to be directed towards the tricuspid valve. The opening of the return port is angled caudally at approximately 45° to the long axis of the cannula and hence it influences the desired position of the return port opening and the direction of the resulting return blood jet. Longitudinal and rotational adjustments of cannula position are frequently required to achieve ideal return flow direction. Moving the patient and patient's head can result in cannula displacement and malposition.

Case report

We describe a case where the malposition of the venovenous bicaval ECMO cannula resulted in venous return being directed into the hepatic veins.

A 43-year-old male was admitted to our intensive care unit with the diagnosis of community acquired pneumonia resulting in a severe hypoxaemic respiratory failure. Chest x-rays demonstrated extensive bilateral diffuse infiltrates. Patient clinical condition progressively and rapidly deteriorated in spite of conventional invasive ventilation and adjunctive supportive measures. A trial of ventilation with High Frequency Oscillation as a rescue measure failed to improve his oxygenation. In view of ongoing refractory hypoxaemia decision was made to initiate ECMO support. A bicaval double-lumen Avalon cannula was inserted via right internal jugular vein under combination of transoesophageal and transthoracic echocardiographic imaging. Adequate position of the cannula was confirmed by echocardiography with Color Doppler mode showing the origin of the return jet from ECMO cannula located within RA and directed towards tricuspid valve. 4.5–5 L/min VV ECMO blood flows were easily achieved with immediate improvement in patient's oxygenation (Figure 2).

It was then noted that patient had repeated episodes of hypoxaemia associated with positional changes to the patients head overnight. Repeat transthoracic echocardiography was subsequently performed. Subcostal windows provided good views of right atrium, inferior vena cava, origin of the superior vena cava and position of the distal part of VV ECMO cannula.

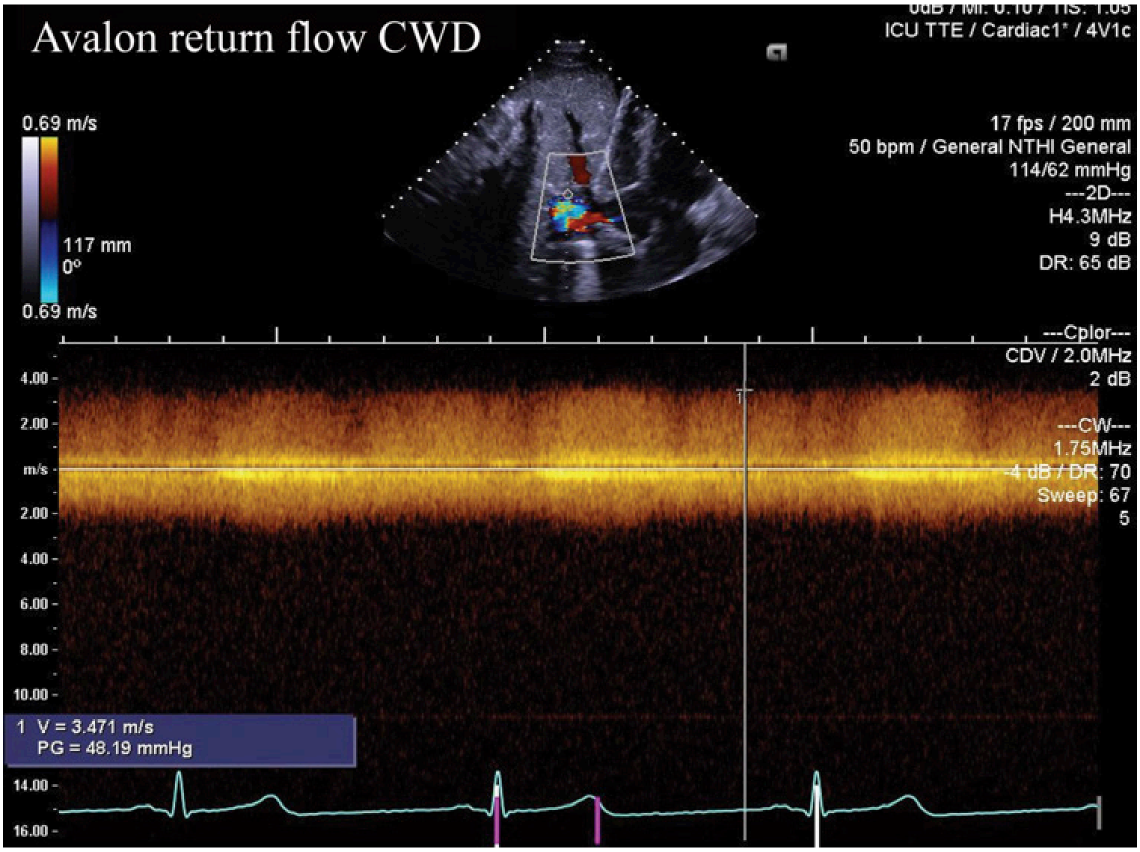

Figure 3: TTE: Subcostal window. Continuous Wave Doppler interrogation of blood flow from the return port of VV ECMO cannula inadvertly positioned in IVC.

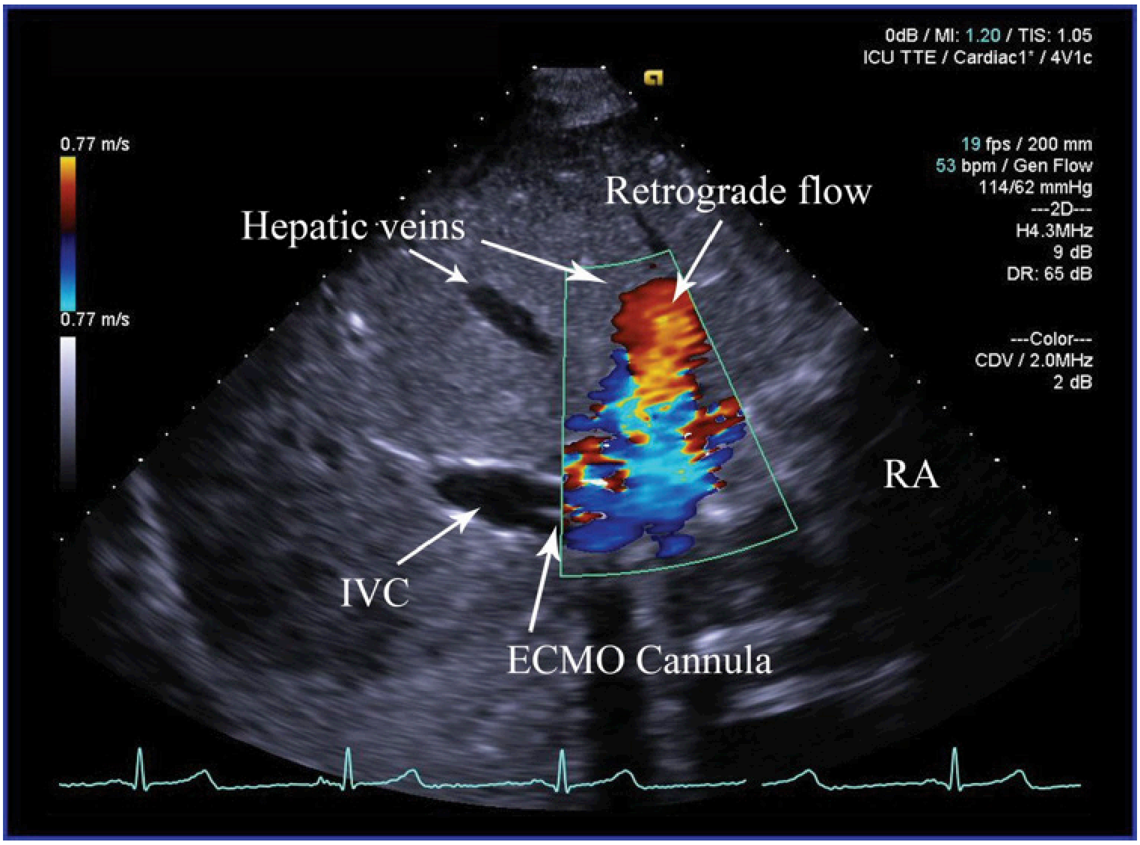

Figure 4: TTE: Subcostal window. Long-axis IVC plane: Color Doppler Mode. Massive continuous retrograde flow is demonstrated into hepatic veins from the return port of VV ECMO Cannula.

Color Doppler interrogation revealed that malposition of the cannula occurred since the last echocardiographic assessment with cannula migrating further into IVC. As a consequence, the return port had also migrated from the right atrium into the IVC; the return jet now being directed straight into hepatic veins. Given that the large ECMO flow of 5 l/min (Figure 3) was now directed against the hepatic venous return, major compromise of hepatic venous drainage was evident by continuous retrograde flow

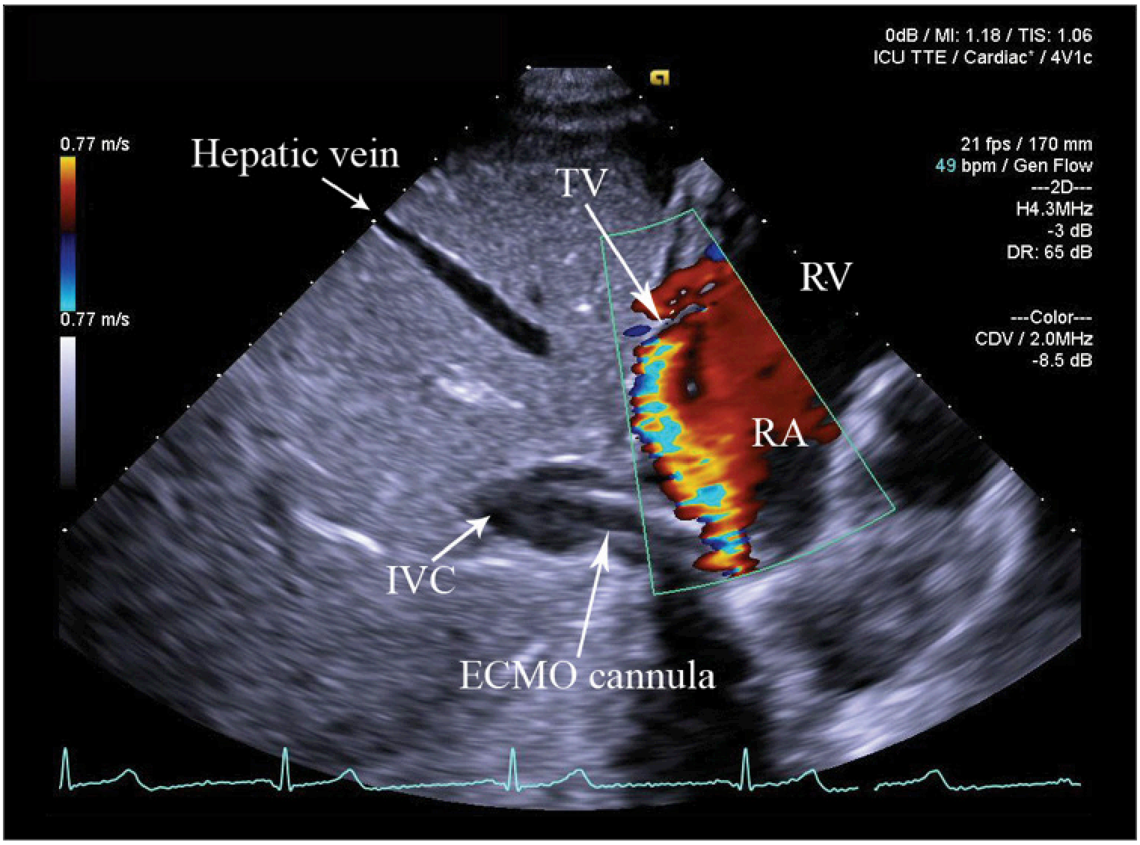

Figure 5: TTE Subcostal window. Long-axis IVC plane. Color Doppler interrogation of jet from the return port of VV ECMO cannula adequately positioned within right atrium and directed towards tricuspid valve post-repositioning of the cannula.

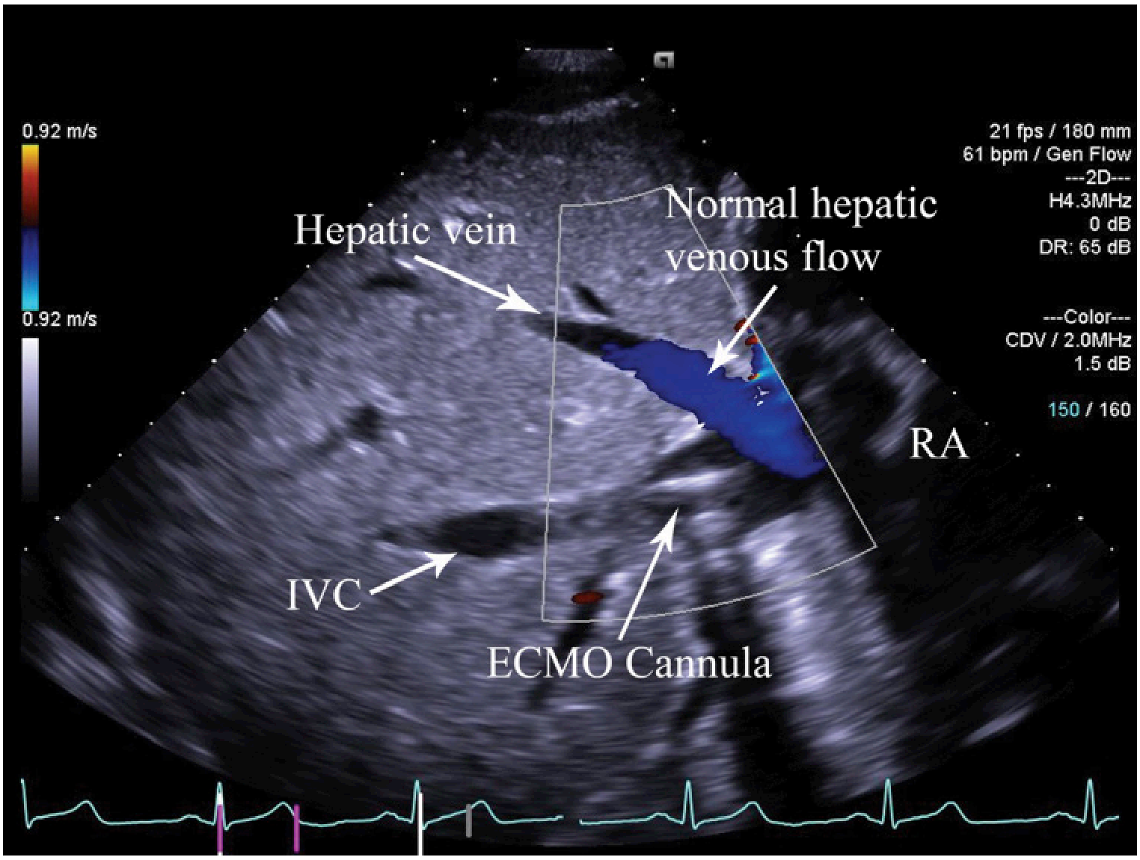

Figure 6: TTE. Subcostal window. Long-axis IVC plane. Normal antegrade hepatic venous flow is demonstrated with Color Doppler after repositioning of ECMO cannula

throughout cardiac cycle (Figure 4). The distance of migration was measured with echocardiography and the cannula was withdrawn under direct echocardiographic guidance restoring correct positioning. Color Doppler confirmed the restoration of appropriate ECMO return flow being again directed towards the tricuspid valve (Figure 5). It further confirmed immediate re-establishment of the antegrade hepatic venous flow (Figure 6). The cannula was re-sutured to skin.

Discussion

It is of prime importance to have bicaval ECMO cannula carefully secured to the neck following insertion to prevent malpositioning. Our practice is to secure the VV ECMO cannulas to the skin by sutures applied at the site of insertion and reinforce it by applying additional sutures to the upper neck. As the insertion is done with neck extended and rotated it is important to remember that when the neck is returned to its normal position with pillow provided for head support, some distal cannula migration can readily take place despite suturing the cannula to the soft tissues of the neck. Anatomically, because of the close proximity between the right atrium, inferior vena cava and hepatic veins, usually there is only a short distance of approximately 2–3 cm available for correct positioning of the return port within the right atrium – between IVC and SVC. This predisposes distal migration of the cannula in a proportion of patients during their movements.

ECMO is conducted with blood flows closely matching patient's native cardiac output to ensure achieving its main purpose, adequate oxygenation. When cannula malposition occurs, such a large flow becomes misdirected. Inevitably, misdirected massive retrograde flow into hepatic veins should result in severe hepatic venous congestion, causing circulatory crisis for the liver and further impairment or even cessation of hepatic portal venous inflow.

Hepatic insufficiency, capsular distension and rupture, severe portal hypertension would then ensure. Acute Budd-Chiari syndrome was previously described in a single case during ECMO circulation conducted via two separate cannulas with femoral-jugular configuration when drainage cannula came to a close proximity to the insertion point of hepatic veins.[6] Hepatic venous thrombosis in that patient resulted in acute derangement of liver enzymes and bilirubin. We are not aware of previous reports describing double-lumen ECMO cannula malposition with blood flow return being misdirected into hepatic veins.

In our case, potential for the damage was worse than in previously described case of Budd-Chiari syndrome, as our patient encountered high reverse blood flow within hepatic venous system. Rapid early echocardiographic diagnosis of double-lumen VV-ECMO cannula malposition prevented potentially lethal complications. We agree with previously suggested in the literature recommendations of routine echocardiographic reassessment of all patients with extracorporeal support conducted via bicaval Avalon cannula (1). We further recommend that immediate echocardiographic re-evaluation of cannula position and flows should be done in patients with unexpected sudden deterioration in oxygenation status and/or onset of haemodynamic compromise. Reassessment of the hepatic venous drainage should be performed in all patients who have IVC ECMO cannulas as a part of a routine echocardiographic study and more so, in cases of hepatic enzymatic derangements or sudden liver impairment.

Conclusions

Double-lumen VV ECMO cannula malposition can result in massive retrograde hepatic venous flow. Regular echocardiographic surveillance is essential for early diagnosis of cannula malposition and for prevention of potentially fatal complications.

References

1 Platts DE, Sedgwick JF, Burstow DJ, Mullany DV, Fraser JF. The role of echocardiography in the management of patients supported by extracorporeal membrane oxygenation. *J Am Soc Echocardiogr* 2011; 25 (2): 1–11.

2 Bermudez CA, Rocha RV, Sappington PL, Toyoda Y, Murray HN, Boujoukos AJ. Initial experience with single cannulation for venovenous extracorporeal oxygenation in adults. *Ann Thorac Surg* 2010; 90 (3): 991–95.

3 Javidfar J, Brodie D, Wang D, Ibrahimiye AN, Yang J, Zwischenberger JB, *et al.* Use of bicaval dual-lumen catheter for adult venovenous extracorporeal membrane oxygenation. *Ann Thorac Surg* 2011; 91: 1763–68.

4 Javidfar J, Wang D, Zwischenberger JB, Costa J, Mongero L, Sonett J, *et al.* Insertion of bicaval dual-lumen extracorporeal membrane oxygenation catheter with image guidance. *ASAIO J* 2011; 57: 203–05.

5 Dolch ME, Frey L, Buerkle MA, Weig T, Wassilowsky D, Irlbeck M. Transesophageal echocardiography-guided technique for extracorporeal membrane oxygenation dual-lumen catheter placement. *ASAIO J* 2011; 57 (4): 341–43.

6 Victor K, Barrett N, Glover G, Kapetanakis S, Langrish C. Acute Budd–Chiari syndrome during veno-venous extracorporeal membrane oxygenation diagnosed using transthoracic echocardiography. *Br J Anaesth* 2012; 108 (6): 1043–44.