A COMPUTATIONAL ANALYSIS OF VESSEL COLLAPSE DUE TO DRAINAGE CANNULA FLOW DYNAMICS DURING VENO-ARTERIAL ECMO

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Introduction

Veno-arterial extracorporeal membrane oxygenation (VA ECMO) is a form of temporary mechanical circulatory support for cardiac and respiratory failure. The drainage cannula is typically inserted into the femoral vein and relies on adequate vessel diameter and wall integrity to sustain blood flow. However, under certain conditions the vessel wall can become compromised, leading to partial or complete collapse around the cannula. This study investigates the hemodynamic effects of vessel wall collapse during VA ECMO using computational fluid dynamics (CFD) simulations.

Methods

A patient-specific geometry of the venous system was extracted from a computed tomography scan of a VA ECMO patient. A 25 Fr Maquet drainage cannula was placed within the venous system with the tip positioned in the superior vena cava - right atrium (SVC-RA) junction. To simulate vessel collapse, manual restriction of the vessel wall around the proximal holes of the cannula within the inferior vena cava (IVC) was implemented in four sequential stages (Figure 1). The hemodynamic outcomes at each stage of vessel collapse were compared with the baseline scenario of no vessel wall collapse. The cannula was prescribed with a 4 L/min suction flow rate to reflect standard adult VA ECMO support.

Results

Collapse of the IVC wall narrowed the flow area, leading to increased blood velocity within the restricted regions. Consequently, this caused a significant rise in wall shear stress (WSS) values. Specifically, the maximum WSS under ideal conditions was 16.4 Pa, whereas during stages 1 to 4 of vessel collapse, the values measured were 39.6 Pa, 148.1 Pa, 497.9 Pa, and 537.2 Pa, respectively (Table 1).

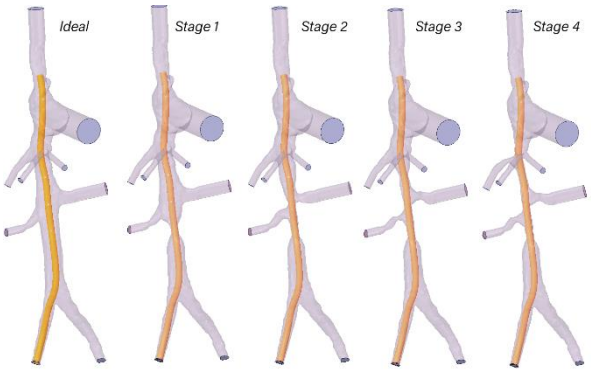

Figure 1: The venous geometry with a cannula at increasing levels of vessel wall collapse. At each stage the holes at the collapse were blocked manually.

Column 1	Average WSS (Pa)	Maximum WSS (Pa)
Ideal	0.51	16.4
Stage 1	0.90	39.6
Stage 2	1.74	148.1
Stage 3	3.46	497.9
Stage 4	5.09	537.2

Table 1: The vessel wall shear stress values at different stages of collapse.

Discussion

The increase in wall shear stress resulting from vessel wall collapse in the IVC can cause endothelial damage and initiate thrombosis during VA ECMO. Elevated blood velocities due to narrowed flow areas lead to significantly higher wall shear stress values, particularly at advanced stages of vessel collapse (stage 3 and stage 4). The fibrin/proteinaceous sheath partially enveloping the cannula could occlude some of the hole rows, impairing venous drainage during VA ECMO [1].

References

1. Marta Velia, et al. ASAIO J, 69(11):p e471-e472, 2023.