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NUMERICAL SIMULATION OF THROMBUS FORMATION INDUCED BY A CENTRAL VENOUS CATHETER

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1. Introduction

Central venous catheters (CVCs) are inserted typically into chemotherapy patient's central veins for drug delivery. However, these in-dwelling catheters may lead to thrombotic complications. Ideally, the catheter tip should be positioned in the middle of the vein and no vessel contact. However, this is not possible clinically. This computational study explores how thrombus formation may occur based on catheter tip position.

2. Materials and Methods

A model was reconstructed from a micro-CT scan of a Teleflex® Arrow double-lumen catheter. A constant flow rate was applied at 3.0 *l/min*, and the blood was assumed to be non-Newtonian [1]. In order to model the thrombus formation, the simulations were transient using a customized pimpleFoam (OpenFOAM version 7.0) solver that incorporated a thrombosis model [2].

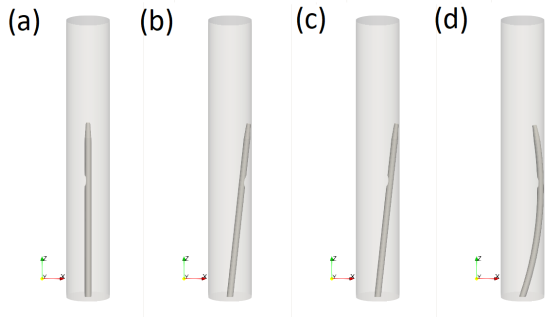

Figure 1: Catheter tip at different positions in an idealized supervisor venous cava (SVC) of 16 mm in diameter. (a): Ideal position. (b): Side-hole facing lumen. (c): Side-hole facing lumen. (d): Curved tip and side-hole facing lumen.

3. Results

Thrombosis simulations after 15 minutes show that the clots were minimal when the CVC was placed in the middle of the vein (Figure 2a). However, a thrombus formed at the contact site and obstructed the tip-hole completely (Figure 2b&c). When the tip was purposely bent away from the vessel wall (Figure 2d), the flow around the tip was not trapped in a low flow region, which prevented clot at the contact site from covering the tip.

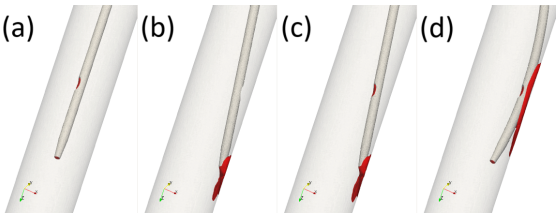

Figure 2: Clots on catheter tip section in four CVC placement positions.

4. Discussion and Conclusions

The study explored the thrombosis potential of different catheter positions. Although the curved tip section would induce a larger clot at the contact site, it could reduce the possibility of occlusion in the tip-hole. This study showed how CVC tip and side hole positioning may influence clot formation.

5. References

1. Yang et al., J. Biomech. 120:110393 (2021).
2. Su et al., Annals of Bio Eng. (accepted) (2024).

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