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Abstract Book

IN SILICO MODELLING OF FLOW-INDUCED COLLAPSE OF BLOOD VESSELS: A COMPARATIVE STUDY OF VOLUME STATUSES

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INTRODUCTION

Compliant human structures, including the upper airways of the respiratory system, urethra, veins in legs, and coronary/ brachial arteries, exhibit collapsibility [1,2]. The collapse of inferior vena cava's (IVC) is of exceptional interest due to its significant physiological implications for the management of patients with chronic and decompensated heart failure (HF). Accurate assessment of volume statuses, such as euvolemia, hypo-/hypervolemia, in these patients is crucial for diagnostic and therapeutic decision-making by clinicians [3].

The objective of this study is to utilize fluid-structure (FSI) simulations in an idealized IVC geometry to achieve two goals: a) estimate the collapse of IVC; and b) compare the 3D collapse with the corresponding hemodynamic field under different volume statues.

MATERIALS AND METHODS

ANSYS Workbench 2021R2 were used to construct an idealized IVC model and to perform the two-way FSI simulations. ANSYS Mechanical and Fluent were used as the structure and fluid solvers, respectively. The data exchange between the two domains was facilitated using the System Coupling feature. For the CFD boundary conditions (BCs), the blood was modelled as an incompressible Newtonian fluid (ρ=1050 kg/m3, μ=0.0035 kg/m·s). The flow was assumed to be laminar and steady, with a Poiseuille velocity profile (V=0.2 m/s).

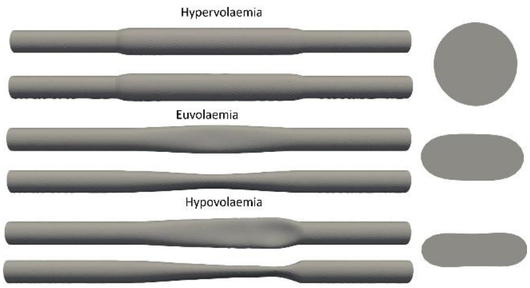

Figure 2: Comparison of vessel deformations with volume statues in different views (left) and the cross section area.

RESULTS

Fig.1 illustrates the deformation of the IVC in the thee investigated volume statuses (left). The cross-sectional areas demonstrate the occurrence of collapse occurred (right). Fig.2 presents the pressure field within the investigated models. Table 1 presents the calculated area and the collapsibility index (CI) for the investigated cases at the location of the maximum collapse. The CI calculated based on IVC diameter and the formula CI (%)=(Dmax-Dmin)/Dmax, as have been established as clinical tools to assess volume statues [4].

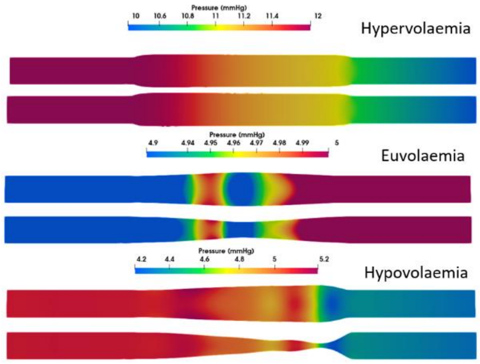

Figure 1: Pressure contour plots with volume statues for in the x-y plane and the x-z plane.

Table1: Calculation of the Area and Collapsibility Index (CI).

Volume Statues	Area (x10^{-3}m^3)	CI (%)
Hypervolaemia	0.356	13.1
Euvolaemia	0.247	37.6
Hypovolaemia	0.215	51.9

DISCUSSION

Here, we present the initial steps towards developing a robust computational framework for simulating IVC vessel collapse using FSI. Our preliminary results, qualitative and quantitative, are in good agreement with previous studies [5,6]. Further investigation is needed to understand the impact of BCs and IVC geometry on the observed hemodynamic alterations and collapse. In our ongoing research, we aim to improve the accuracy of the collapsible IVC model by optimizing the ANSYS coupling system and incorporating realistic flow and wall material properties. By enhancing the reliability of our framework, we anticipate gaining deeper insights into this complex phenomenon, advancing medical understanding, and potentially improving diagnostic and therapeutic strategies.

REFERENCES

1. C.D. Bertram, *et al., J Biomech Eng., 1989*
2. D.J. Eckert, *et al.,* Proc Am Thorac Soc., 2008
3. J. Raco, *et al.,* Cardio Res, 2023
4. L. Rudski, *et al., J Am Soc Echocardiogr, 2010*
4. Hazel,*et al.,* JFM, 486, 79-103 2003.
5. Marzo, *et al.*, J. Fluids Struct, 20(6), 817-835, 2005