CARDIAC OUTPUT INFLUENCE ON THE FLOW IN A TRI-LEAFLET MECHANICAL HEART VALVE

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Introduction

Only little data is available on the hemodynamic performance of prosthetic heart valves at reduced and increased cardiac output (CO) as most studies were done for CO of 5L/min [1]. This study aims to close this gap by investigating the blood flow patterns for low CO (LCO) and elevated (ECO) in a tri-leaflet mechanical heart valve implanted in aortic position in comparison to blood flow patterns at normal CO (NCO).

Methods

A pulse duplicator with a multi-view imaging system (Tomo-PIV) [2] was employed to investigate the flow characteristics in the aortic root of a tri-leaflet MHV (TRIFLO 21mm, Novostia). The valve was tested at low (3 l/min), normal (5 l/min) and elevated CO (7 l/min) under hypotensive (60/40mmHg), normotensive (120/80mmHg) and hypertensive (110/180mmHg) pressure condition respectively [3]. The heart rate was set to 70 bpm. Flow topology, mean flow velocity, and turbulent kinetic energy (TKE) were extracted from the measured flow field throughout the cardiac cycle.

Results

All three haemodynamic configurations exhibited one central jet and three side jets at the sinus level. For increasing CO, jet impingement occurred further downstream the aortic root (*Figure 1*).

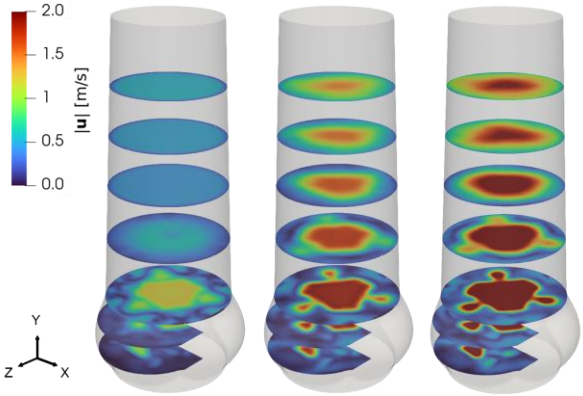

Figure 1:Mean flow rate at peak systolic. From left to right: low CO (t=190 ms), normal CO (t=150 ms) and elevated CO (t=130 ms).

The systolic jet took longer to fully develop in LCO resulting in delayed development of turbulence, such that peak TKE in the aortic root appeared later and lower (Figure 2). The opposite could be observed by comparing ECO with NCO. Results at peak systole are summarized in Table 1.

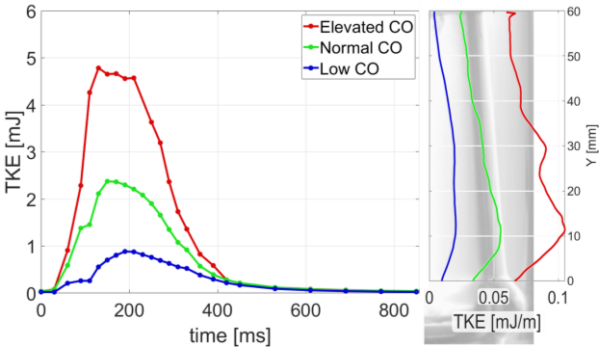

Figure 2: TKE calculated at different time instances through the cardiac cycle (left). TKE calculated along the central axis for peak systole.

	$\|\mathbf{u}_{max}\|$ [m/s]	TKE [mJ]	Backflow* [l/min]	$Y^*_{imp.}$ [m]
LCO	1.28 (-37%)	0.88 (-63%)	1.25 (-42%)	17 (-12.8%)
NCO	2.02 (-)	2.38 (-)	2.14 (-)	19.5 (-)
ECO	2.76 (+37%)	4.78 (+100%)	2.44 (+14%)	22.5 (+15%)

Table 1: Computed values at peak systole. Values are in comparison to NCO.
** Computed at/from the sinotubular junction.*

Discussion

Variations in CO do not translate to a simple rescaling of the haemodynamic parameters characterizing the aortic flow. Reducing the CO shows significant lower turbulent kinetic energy as well as a jet impingement further upstream resulting in a spatially reduced influence of the valve on the flow in the ascending aorta. In all three conditions, the TKE peak is reached in the downstream vicinity of the sinotubular junction. Independently of the flow rate, the flow in the sinus does not seem to show fully developed turbulence.

References

1. Pietrasanta L et al. Frontiers in Cardiovascular Medicine. 2022;8:804565.
2. Hasler D et al, Experiments in Fluids, 2016;57(5):80.
3. International Standard: ISO 5840-2, Second edition, 2021-01