HAEMODYNAMIC ANALYSIS OF DIFFERENT SURGICAL STRATEGIES OF A TYPE-B AORTIC DISSECTION VIA VIRTUAL GRAFTING

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Introduction

Compliance mismatch between the aortic wall and Dacron grafts (DG) commonly employed in aortic surgery is a recognized clinical problem concerning aortic haemodynamics and morphology degeneration [1]. The rigidity induced by DGs can lead to an increased left ventricle (LV) afterload and extra aortic tearing. In this study, we quantify the impact of the compliance mismatch by virtually testing different surgical Type-B aortic dissection (TBAD) grafting strategies using patient-specific computational fluid dynamics (CFD) compliant simulations.

Methods

A TBAD patient was presented at St Bartholomew's Hospital and treated with a 130 mm thoracic DG. Post-op CT scans were segmented and used as a baseline for analyzing different surgical strategies. After consultation with the clinical team, three virtual grafting strategies were explored *in silico;* these comprised different DGs lengths corresponding to mid, full descending aorta (MDA, FDA) and full aorta (FA) replacements.Two additional cases with compliant DGs were studied, one (G1) with a patient-specific aortic wall compliance and a second one (G2) with twice this value. The blood flow was modelled using a moving boundary method [2] to capture aortic wall displacement. Patient-specific 2D flow MR-driven inlet flow rate and dynamic outlet boundary conditions were employed. The aortic wall stiffness was calculated from cine-MRI. The energy loss (EL) and stroke work (SW) linked with LV afterload and wall shear stress (WSS) driven metrics, such as the endothelial cell activation potential (ECAP) related to aneurysmal degeneration, were computed.

Results

A stiffer aorta and more extended grafting (MDA,FDA) were found to be associated with increased aortic pressure, EL and SW and a vertical shift in the pressure-volume loops (Table 1), with the exception of FA which lowered EL by 34%. Implementing a patient-specific compliant graft reduced the pulse pressure by 11% and the EL by 4% (see case G1, Table 1).

	Psys [mmHg]	Pdia [mmHg]	Stroke Work [W]	Energy Loss [W]
Post-op	97.5	68.4	0.65	85.0
MDA	100.1	68.9	0.71	87.4
FDA	101.5	70.9	0.73	88.9
FA	101.7	72.0	0.66	63.3
G1	96.2	69.9	0.64	82.4
G2	99.8	69.6	0.66	83.3

Table 1: Aortic systolic and diastolic pressures, stroke work and energy loss for the six cases.

The distribution of pressure and WSS indices varied among the surgical strategies explored. The aneurysmal and top sutures regions showed the largest differences in time average wall shear stress (TAWSS) and endothelial cell activation potential (ECAP) between the post-op and the virtual grafting cases (MDA,FDA) as shown in Figure 1.

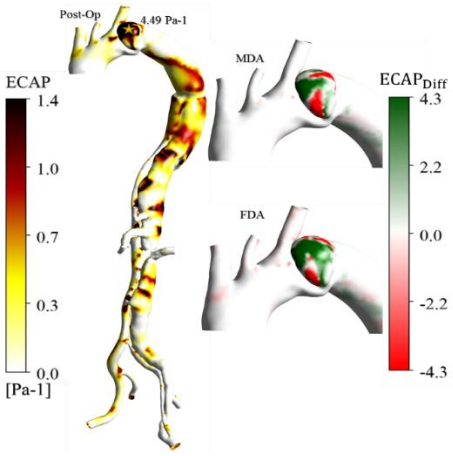

Figure 1:Left is the ECAP distribution in post-op case with its maximum value indicated by a yellow star. Right is a zoom on the aortic arch showing the difference in ECAP values between post-op and the MDA and FDA cases.

Discussion

The impact of compliance mismatch in TBAD was examined virtually. Our results indicate that lowering aortic compliance by increasing the rigid DGs' length tends to augment the pressure, SW and EL. Exploring various graft intervention strategies can thus aid clinicians to optimise treatment in complex TBAD. The study also illustrates that benefits can be realised when grafts are made compliant implying that biomimetic grafts should be considered by manufacturers to lower patient risks of LV hypertrophy and heart failure [3].

References

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Acknowledgements

This project was supported by the funded projects "VIRTUOSO" (NH/20/1/34705), “PIONEER project EP/W00481X/1 and “MEDICARE” project BB/X005062/1 as well as the Welcome EPSRC Centre for Interventional and Surgical Sciences (WEISS, NS/A000050/1). The study was ethically approved by St Bartholomew's Hospital BioResource ethical application number 97.