Patient-specific modelling for the assessment of the hemodynamics risk of failure in endovascular aneurysm repair

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Abstract

Endovascular aneurysm repair (EVAR), despite its advantages over abdominal aortic aneurysm (AAA) open surgery, still presents risks of failure linked to Endograft (EG) migration. We here explore the link between intravascular blood flow features and Displacement Forces (DFs) acting on the EG. DFs are inversely associated with the amount of helical flow within the EG.

Introduction

Recently, EVAR is becoming increasingly adopted for the treatment of AAA thanks to its low morbidity rate and invasiveness. However, EVAR procedure presents complications, in particular EG migration leading to its failure. Here we analyze the in-stent hemodynamics in image-based computational fluid dynamics 3D models of post-EVAR patients treated with commercial EGs,[1,2] exploring the associations between distinguishable hemodynamic features and DFs. The idea is to identify a hemodynamic quantity as potential target of EGs design optimization strategies, with the final goal of minimizing EVAR failure risk. The adopted approach has the potential of improving EG design reducing animal testing.

Materials and Methods

10 subjects treated with Endurant® (Medtronic, CA, USA), and 10 with Excluder® (Gore Medical, AZ, USA) EG were analyzed.[1,2] From 1-month post-implantation CT scans, 3D geometries were reconstructed. Computational fluid dynamics analysis was performed as described elsewhere.[1,2] The resultant of the cycle-averaged DFs (TADF) was evaluated as given by the action of blood pressure and fluid shear stress on the EG inner surface. In-stent helical flow patterns were visualized in terms of local normalized helicity (LNH)[2] and quantified computing cycle-averaged helicity intensity (h_2).[2]

Results and Discussion

On average, TADF magnitude in Endurant patients was higher than in the Excluder group (2.52±1.61 N vs. 1.58±0.65 N). Qualitatively, a lower production of helical flow was associated with higher displacement forces (Figure 1, where only the Endurant models with the highest and the lowest peak DF magnitude values are presented). Quantitatively, helical flow intensity h_2 was inversely associated to TADF (Figure 1), *i.e.*, the higher is h_2, the lower the DFs.

To conclude, this study suggests that helical flow-driven strategy applied to EVAR devices could minimize the clinical risk of EG migration.

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Key words: AAA; EVAR; helical flow; displacement forces.

Conference presentation: This paper was presented at the Third Centro 3R Annual Meeting - L'era delle 3R: modelli *in silico, in vitro* e *in vivo* per promuovere la ricerca traslazionale - 30 September - 1 October 2021, Evento online organizzato dal Politecnico di Torino.

Received for publication: 9 July 2021.
Accepted for publication: 7 September 2021.

Biomedical Science and Engineering 2021; 4(s1):175
doi:10.4081/bse.2021.175

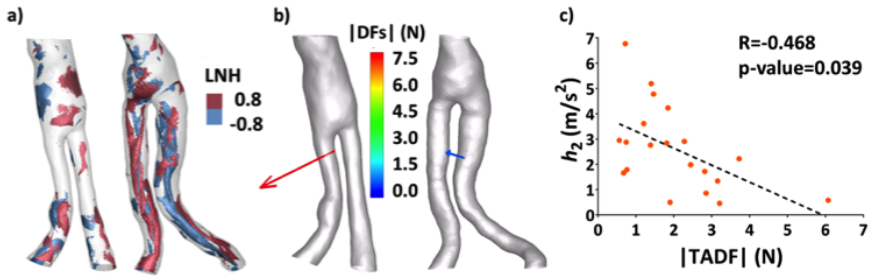

Figure 1. Colormaps of two explanatory cases for: a) LNH and b) resultant DFs at peak value. c) Scatter plot between |TADF| and h_2.

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