

DISTURBED FLOW PATTERNS IN NATIVE PATIENT-SPECIFIC SIDE-TO-END AV FISTULAE FOR HEMODIALYSIS

Bogdan Ene-Iordache¹, Cristina Semperboni², Gabriele Dubini², Andrea Remuzzi^{1,3}
¹Mario Negri Institute, Bergamo; ²Politecnico di Milano, ³University of Bergamo Italy

Introduction

Radial-cephalic native arteriovenous fistula (AVF) is the first choice for providing vascular access (VA) for hemodialysis (HD) [NKF/KDOQI, 2006]. In our days the AVF surgery has important early failure rates due to stenosis development in the draining vein. We have recently shown, in idealized models of AVF, that disturbed flow (i.e. low and oscillating wall shear stress triggering intimal hyperplasia, IH) occurs in focal points that locate well the sites of future stenosis [Ene-Iordache, 2012]. At that time we speculated on a local remodelling mechanism for AVF stenosis induced by the local disturbed flow. The present study was aimed at investigating whether disturbed flow occurs also in patient-specific models of AVF, that would confirm our hypothesis on mechanism of local development of IH.

Methods

We used magnetic resonance images (MRI) obtained in two patients starting HD treatment, approximately 40 days post-operatively. Reconstruction of 3D models of the AVF was done by using vmtk [Antiga, 2008], an image-based modelling framework for patient-specific computational hemodynamics. We then performed transient flow simulations employing specific blood volume flow and division ratio boundary conditions in the two subjects, using an adaptive mesh refinement solver for large-scale simulation of biological flows [Botti, 2010]. In the post-processing phase, we localized disturbed flow areas by means of hemodynamic wall parameters, the oscillatory shear index (OSI) [He, 1996] and the relative residence time (RRT) [Himburg, 2004].

Results

Disturbed flow patterns for the two patient-specific radial-cephalic AVF cases are presented in Figure 1. Three disturbed flow zones (high OSI, as reported in Fig. 1) are located along the distal artery wall (A), on the inner wall of the juxta-anastomotic vein (B)

and along the inner curvature of the draining vein (C), respectively. The same pattern was observed in both anastomosis models.

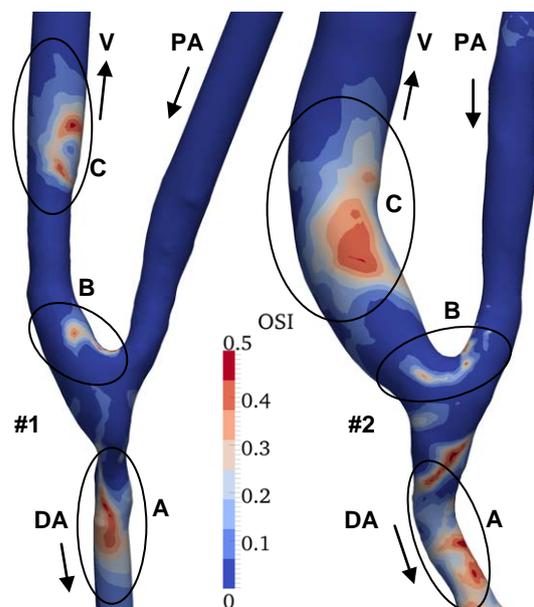


Figure 1: Patterns of disturbed flow on the two patient-specific AVF wall. PA, proximal artery; DA, distal artery; V, vein; arrows indicate the direction of flow during the CFD simulations.

Discussion

Our hypothesis of local remodelling mechanism for AVF stenosis [Ene-Iordache, 2012] was corroborated also in patient-specific AVF. By using unsteady CFD modelling in patient-specific radial-cephalic AVF, we have found that low and oscillating hemodynamic shear stress in the post-operative flow condition are contributing factors of the pathogenesis of intimal hyperplasia, that is responsible for the localization of vessel stenosis and AVF failure.

References

- NKF/KDOQI, *AJKD*, 48, S176-247, 2006.
- Ene-Iordache B & Remuzzi A, *NDT*, 27:358-68, 2012.
- Antiga L *et al*, *Med Biol Eng Comput*, 46:1097-112, 2008.
- Botti L *et al*, *Int J Numer Meth Eng Biomed*, 26:86-100, 2010.
- He X & Ku DN, *J Biom Eng*, 118:74-82, 1996.
- Himburg HA *et al*, *AJP*, 286:H1916-22, 2004.