

INVESTIGATING FLOW UNSTEADINESS IN REALISTIC AND OPTIMISED ARTERIOVENOUS FISTULAE

Introduction: Native arteriovenous fistulae (AVF) for haemodialysis are susceptible to non-maturation due to the formation of peri-anastomotic neointimal hyperplasia. Highly oscillatory flow patterns, low levels of wall shear stress, and wall hypoxia are all implicated in the development of neointimal hyperplasia, and hence the failure of AVF. Computational fluid dynamics (CFD) studies have linked vascular curvature with suppression/enhancement of highly oscillatory flow patterns inside the artery using steady (non-pulsatile) inflow boundary conditions in fully-idealised geometric configurations.

Methods: In this study, the commercial CFD solver STAR-CCM+ was used to perform direct numerical simulations of pulsatile blood flow in various AVF configurations. Specifically, simulations were undertaken in semi-idealised configurations obtained via connecting an idealised vein onto healthy realistic arteries (based on CT scan data) to understand how AVF geometry (in particular vascular curvature) alters flow patterns within AVF. Subsequently, a Kriging-based optimisation method was utilised to identify fully-idealised AVF configurations that reduce flow unsteadiness in the artery and the vein.

Results: The results of the semi-idealised simulations show that arterial curvature has a dramatic impact on flow patterns within AVF. Specifically, contrary to non-pulsatile conditions it was found that flow in both the arterial and venous segments of the AVF could be unsteady, irrespective of whether the vein is connected to the inside or outside of an arterial bend. However, fully-idealised AVF configurations identified via a Kriging-based optimisation method were found to suppress flow unsteadiness in the whole AVF.

Conclusion: Semi-idealised simulations suggest that, under pulsatile flow conditions, flow in both the arterial and venous segments of an AVF can be unsteady, irrespective of whether the vein is connected to the inside or outside of an arterial bend. However, fully-idealised AVF configurations were identified that suppress highly oscillatory flow patterns.