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Blood flow in an intracranial aneurysmal artery with a dual-layer stent

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Intracranial aneurysms are focal dilatations of arteries in the cerebral vasculature that require surgical intervention once detected. Dual-layer flow-diverting stents are the latest innovation intended for the endovascular treatment of intracranial aneurysms. A fine-mesh device, comprised of a low porosity inner stent and a high porosity outer stent, is implanted within the parent artery bearing the aneurysm. The inner layer is designed to alter the haemodynamics of both the aneurysm and parent vessel, and is therefore the active flow-diverting element, while the outer layer ensures the patency of nearby perforating arteries[1,2]. The FRED (Flow-Redirection Endoluminal Device) stent is the first device of its kind, with clinical approval in European and international markets. Several studies investigating the efficacy of the FRED stent have found its design to be safe and effective in the treatment of difficult-to-treat or otherwise untreatable intracranial aneurysms[2,3]. However, clinical radiological post-procedural data is limited. As of January 2018, only 370 patients across ten studies reported the efficacy of the FRED device, with primarily saccular and small aneurysms being treated. This work is the first detailed computational fluid dynamic analysis of blood flow in a section of an intracranial aneurysmal artery after treatment with a dual-layer stent. In particular, two-dimensional computational models implemented a virtual bench test to investigate local haemodynamic changes in part of the treated vessel. Preliminary results consider steady flow conditions, based on a parabolic inlet profile, for the solution of the incompressible Newtonian Navier-Stokes equations. Computational fluid dynamic analysis focussed on the variance of flow parameters, including velocity, pressure, vorticity, and wall shear stress, for three dual-layer stent models: a baseline model with the same number of total wires as the FRED stent on both layers; an alternative model with half the number of wires in the outer layer; and a second alternative model with half the number of wires in the inner layer[4]. The most favourable flow behaviour in the aneurysmal artery was observed for the design in which the outer layer has half the number of wires than the inner layer. For all designs, the radial clearance between the two layers was seen to reduce the velocity of the surrounding blood flow to 98% of the blood flowing at the vessel centre. This research provides an aid to quantitatively estimate the flow of blood in a dual-layer treated vessel and will facilitate the optimisation of such devices.

References

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