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Manufacture-Oriented Design Optimisation of a Flow Diverter Stent Using Lattice Boltzmann Method and Simulated Annealing

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Abstract

Background: Flow diverter (FD) intervention is becoming increasingly popular for treatment of cerebral aneurysms (CAs), but post-stenting complications such as delayed rupture and post-stenting stenosis are frequently reported.

Purpose: To reduce the risk of post-stenting complications, we designed an optimisation method for a practical FD composed of 3D helix-like wires using intra-aneurysmal maximum velocity (AMV) as the optimisation objective.

Method: Random modification was performed at each stage to assign a slight change to the starting phase of an arbitrarily selected sub-wire, followed by computational fluid dynamics simulation to model the corresponding haemodynamic behaviours. The optimisation process employed a combination of lattice Boltzmann fluid simulation and simulated annealing. The method was applied to two idealized aneurysm geometries: the straight (S) and curve (C) models.

Results: We evaluated the flow reduction R_f by measuring the AMVs before and after design optimisation with respect to the non-stented case. The R_f of the FD in the S model showed an improvement from 83.63 to 92.77%, and the R_f for the C model increased from 92.75 to 95.49%, both having reached a pre-defined convergence status. By visualizing the streamlines entering an aneurysm after optimisation, we found that an efficient FD design may be closely associated with the disruption of the bundle of inflow by strut placement inside inflow area.

Conclusions: The method improved the flow-diverting performance of an FD while maintaining its original porosity and helix-like structure. This study has provided a design optimisation method for the most commonly used helix-like FD devices.

Keywords: cerebral aneurysm, flow diverter, design optimisation, computational fluid dynamics.