Computational comparison of spiral and non-spiral peripheral bypass grafts

Kokkalis E1,2, Hoskins PR3, Valluri P4, Corner GA5, Duce SL2, Houston JG2
1Institute for Medical Science and Technology, 2Cardiovascular and Diabetes Medicine, University of Dundee, Dundee, UK. 3Centre for Cardiovascular Science, 4Chemical Engineering, University of Edinburgh, Edinburgh, UK. 5Medical Physics, Ninewells Hospital and Medical School, Dundee, UK

Introduction
Restenosis in the distal anastomosis of peripheral vascular grafts remains the main reason of occlusion and is related to haemodynamics. Single spiral flow (Fig. 1) is a normal feature in vessels [1]. Grafts designed to generate a single spiral outflow (VFT Ltd, Dundee, UK) have been introduced in clinical practice. A spiral graft was compared with a control graft using image-guided modelling.

Methods
- Both grafts were housed in ultrasound flow phantoms (Fig. 2).
- Each phantom was scanned with CT (Biograph mCT, SIEMENS, Germany) and the graft-vessel mimic lumen geometry was extracted with Amira (FEI, France) (Fig. 3).
- Volume meshes were created (ICEM CFX, ANSYS, Canonsburg, USA) and the flow was simulated (ANSYS CFX).
- The blood was assumed Newtonian, homogeneous and incompressible, the walls rigid and the inflow a steady parabola (Reynolds 620, 935).
- The flow fields downstream from the outflow of the spiral and control models were compared.
- The vortical structures at cross-flow patterns 1 – 4 (Fig. 2a) were previously studied experimentally with vector Doppler imaging (Fig. 4b-d), which was used for validation [2].

![Image](image_url)

Results
- Fig. 4 shows a comparison between the computational and experimental flow maps at cross-flow plane 1 (Fig. 2a).
- A single spiral was found in the outflow of the spiral graft and a double or triple spiral in the outflow of the control (Fig. 5).
- The maximum in-plane (tangential) velocity and total circulation at cross-flow planes 1 – 4 were higher for the spiral graft model (Fig. 6).
- Helicity in the volume between plane 1 and 4 was higher for the spiral model (Fig. 7).
- Pressure drop over length from the graft inlet to cross-flow plane 4 was reduced for the control graft model (Fig. 7).

![Image](image_url)

Discussion
The flow pattern generated by the spiral graft was related to reduced flow separation, stagnation and instability (Fig 5). The increased in-plane velocity, circulation and helicity of the spiral device showed increased in-plane mixing, which may protect endothelial function [3]. Pressure drop is not desirable; however the detected difference was negligible (physiologic pressure 1 – 20 x 10^4 Pa). Increased WSS is considered atheroprotective, although this may not apply in the proximal flow where the blood impinges abnormally on the wall of the host vessel [4].

Conclusions
The spiral graft was able to reintroduce a single spiral pattern in its outflow, associated with coherent and high intensity cross-flow phenomena. Such local haemodynamics are known to prevent neointimal hyperplasia and thrombosis [1,2]. These results support the hypothesis that spiral grafts may improve patency rates in patients.

References