HAEMODYNAMICS OF PERIPHERAL ARTERIAL BYPASS GRAFTS

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Abstract. The patient's own (autologous) vein is the preferred material for bypass grafting of arteries of the lower limbs. However, an adequate autologous vein is not always available and the use of a prosthetic graft may be the only alternative to amputation of a critically ischemic limb. Prosthetic grafts such as those made of expanded PTFE have very poor performance. Failure is often due to the development of intimal hyperplasia which leads to narrowing at specific sites at the junction between the graft and the recipient artery, or anastomosis. The intimal hyperplasia is progressive and in many cases will result in total occlusion of the bypass. Improving the performance of prosthetic bypass grafts is therefore an important area of research and will have significant impact on the treatment of patients with critical ischaemia. The mechanisms responsible for the development of intimal hyperplasia are not fully understood but there is strong evidence that hemodynamic forces play an important role. There is experimental and clinical evidence to suggest that the local blood flow patterns, specifically, the distribution of wall shear stress has an influence on the development of intimal hyperplasia. It is well known that intimal hyperplasia tends to develop in regions of low mean wall shear stress whilst it is inhibited in areas of moderately high wall shear stress. Geometry is one of the most important factor that affects the local blood flow pattern and the distribution of shear stress. This has led to the concept of anastomotic engineering whereby the arterial graft is designed to provide blood flow patterns that are conducive to minimisation or suppression of intimal hyperplasia. While most prosthetic bypass grafts have a uniform cylindrical geometry, we have developed PTFE grafts that incorporate a cuff-like widening at the distal end. We have investigated the flow patterns in life-size models of these and standard bypass grafts. The studies are based on particle flow visualisation technique and laser Doppler velocimetry measurements under simulated pulsatile flow conditions. We have also investigated the influence of non-planar geometry of the bypass on flow patterns. The principal feature of the flow in a cuffed graft is a large vortex which forms at the peak of the cardiac cycle and subsequently occupies most of the cuff. This Dean type vortex is coherent and spins in one direction from its onset until the end of the cycle. With the arrival of the next cycle, the vortex is completely dissipated and particles that were previously circulating in the vortex are washed away. This ensures that the residence time is minimized and consequently the exposure of the walls to activated platelets in the circulating blood is also minimized. The presence of the vortex alters the distribution of wall shear stress in the anastomosis such that regions of low wall shear stress are located within the cuff region and away from the recipient artery. These results show that the flow patterns are strongly dependent on the geometry of the anastomosis, the distribution of blood flow in the recipient artery and the pulsatility of the flow. The effect of non-planar geometry is to generate a swirl which may have important implications for the distribution of wall shear stress in the recipient artery. The anastomotic engineering approach to generate favourable haemodynamics may potentially reduce intimal hyperplasia and improve the performance of peripheral bypass grafts.