Prediction of Patency in Blood Vessel Grafts by Laser Doppler Flowmetry

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Introduction: The objective of this investigation was to increase knowledge of the relationship of vascular compliance to disturbed flow at the intimal wall. The purpose was to evaluate the capabilities of Laser Doppler Flowmetry (LDF) to non-invasively monitor intimal wall blood flow disturbances in pulsatile arteries as a function of vessel compliance changes. Non-compliant e-PTFE (Goretex) and modified human umbilical vein (Biograft) vascular grafts (UVG) were employed as arterial surrogates in the testing of LDF system capabilities.

The comparison of employed blood vessel grafts, e-PTFE and umbilical vein graft (UVG), was addressed in numerous clinical reports[1, 2, 3]. These studies showed evidence that UVG had much better patency rates than Goretex grafts, in short and long term periods. Although there are many factors that contribute to a blood vessel graft's patency, previous descriptions and documented studies showed there is a strong correlation between grafts' compliance and their patency rates.

The most common complication for vascular grafts remains the progression of intimal hyperplasia (IH). The development of IH is strongly associated with disturbed ("distributed") blood flow caused by compliance mismatch with the surrounding vessel[4].

Methods: Laser Doppler technique was employed in this project to monitor intimal-wall disturbed flow in blood vessel grafts. Recordings of the highest and lowest LDF value exhibited at each site makes it possible to examine wall-flow velocity fluctuations that occur in experiments. Based on the principle of LDF, uniform latex (styrene divinylbenzene) particles, with the diameter 7.6μm, were applied as surrogates for red blood cells. From pilot experiments, it was determined that the average LDF value difference at mid-graft areas of fully developed flow never exceeded 0.2 (about 0.10 to 0.13). Hence, 0.2 LDF difference (approximate 2 mm/sec difference) was taken as the reference fluctuation factor to define "disturbed flow".

Synthetic graft (Goretex®) and umbilical-cord-vein-based Dardik Biograft ® blood vessel substitutes were utilized in this investigation. Sutures and adhesive tapes were used to constrict the grafts to simulate decreased local compliance at an anastomosis or in the lumen (stenosis). Additionally, a stent catheter was applied to determine how its induced local compliance change would modify the sites of potential disturbed flow at adjacent intimal wall locations.

Results: There were two Computational Fluid Dynamics (CFD) models created to simulate the in vitro Goretex graft experiments, one in an unconstrained condition and the other was constrained with suture in its middle position (56% area stenosis). There was a good correlation between CFD "rigid-wall" models and actual experimental results for near-wall intimal disturbed flows in the stiff Goretex vascular graft, but not in the more compliant Biograft. For Biograft, in the 57% area stenosis condition (Fig1), evidence of disturbed flow obviously appeared at the pre-stenotic region. Such high velocity (~60 mm/sec) disturbed flow could induce significant endothelial wall changes. Extremely low intimal flow velocity was observed (at position 12) just following the stenosis region. For the stented experiment, an exceptionally low flow velocity was observed at the middle region of the stent suggesting that this location would be most susceptible to secondary stenotic deposits, and thrombosis.

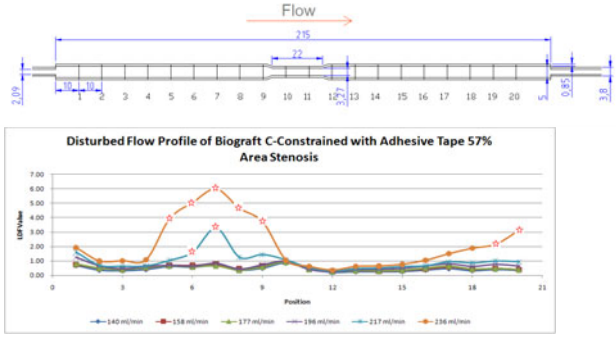

Figure 1. Disturbed flow profile of Constrained Biograft

When the Goretex graft was further constrained with a suture band in the central position**,** an exceptionally low flow velocity occurred at both pre- and post-stenosis sites, where there were apparent recirculation flow regions. When a Biograft was constrained with suture and adhesive tape, there was more disturbed flow which accompanied higher net flow velocity at pre-stenosis regions, especially when the flow rates were high. However, as with results for the Goretex graft, the Biograft showed recirculation flow with very low flow velocity at the post-stenosis position in both constrained conditions. Recirculation flow with extremely low flow velocity was observed at the pre-set stenosis region where a stent was deployed.

Conclusions: This investigation demonstrated the feasibility of using LDF apparatus to non-invasively detect disturbed flow in vascular grafts. The results indicated this LDF technique could be useful for future vascular stent design examination. Since disturbed flow not only occurs at sites of tested stenosis and stented regions, but also at bifurcations, T-junctions, and aneurysms[5], it would be interesting and worthwhile to determine near-wall flow profiles of these suspected disturbed-flow sites. Additionally, the LDF method can be used to evaluate vascular graft closure techniques, such as Bioglue® and fibrin glue applied at anastomoses or patch sites.

References:

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