A COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF PROLONGING SURVIVAL IN THE MICROVASCULAR VEIN GRAFTING

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A Computational Fluid Dynamic Analysis of Prolonging Survival in the Microvascular Vein Grafting

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LIST OF ABBREVIATIONS

2-D	Two Dimensional
3-D	Three Dimensional
CPU	Central Processing Unit
CFD	Computational Fluid Dynamics
FVM	Finite Volume Method
OFE	Optical Flow Estimation
RBC	Red Blood Cell
RSVG	Reverse Saphenous Vein Graft
SI	Le Système international d'unités (International System Of Unit)
UDF	User Define Function
WSS	Wall Shear Stress

LIST OF SYMBOLS

A	Area
γ	Specific weight
C	Integration Constant
Δ	Change in
∂	Partial Difference of
g	Gravity
N	Newton
P	Density
∇	Divergence
Q	Flow rate
$\sum$	Summation
τ	Shearing Stress
μ	Viscosity
V	Velocity
$\overline{V}$	Average velocity
V	Volume

ANALISIS PENGIRAAN BERKOMPUTER BENDALIR DINAMIK KE ATAS CANTUMAN VENA MIKROVASKULAR BAGI MEMANJANGKAN KEMANDIRIAN

ABSTRAK

Penyakit arteri digital yang melibatkan anggota bahagian atas jarang berlaku tetapi masih memerlukan prosedur revaskularisasi. Maka pembedahan pintasan vena atau perantaraan vena dilakukan sebagai tindakan lanjut. Walaubagaimanapun, terdapat satu atau lebih diameter dalaman Reverse Saphenous Vein Graft (RSVG) yang diguna pakai tersumbat dan mengecil dengan teruknya kerana pembentukan geometri yang luar biasa seperti ketidaksamaan diameter dalaman dan kekusutan lebihan panjang selepas menjalani prosedur revaskularisasi. Menurut kajian lalu, pembentukan geometri yang ganjil, percanggahan saiz dan pembengkokan dalam salur darah menyebabkan aliran darah menjadi tidak normal dan menjadi punca kepada pembentukan thrombosis. Tambahan pula, kajian mereka yang terdahulu disokong oleh teori. Objektif penyelidikan ini adalah untuk mengkaji kesan aliran darah keatas model-model graf vena yang mengalami ketidaksamaan diameter dalaman dan kekusutan lebihan panjang yang mengaitkan pelanjutan jangka hayat mereka sendiri. Kaedah pengiraan berkomputer bendalir dinamik dalam tiga dimensi di guna pakai untuk menyelidik halaju, perbezaan tekanan dan tekanan ricih dinding ke atas model RSVG yang lurus ideal dan model-model yang mengalami pembentukan geometri yang luar biasa. Melalui kajian ini, kami menjangkakan aliran darah laminar yang berdenyut akan menunjukkan aliran yang tidak mengikut sifat hidrauliknya dalam model-model RSVG geometri yang luar biasa berbanding dengan model graf vena yang lurus ideal walaupun dalam ujian aliran darah berkeadaan tetap. Secara kesimpulannya, keputusan menunjukkan nilai tinggi pada halaju, perbezaan tekanan dan tekanan ricih dinding dalam permasalahan ketidaksamaan tetapi nilai yang rendah pada halaju, perbezaan tekanan dan tekanan ricih dinding dalam permasalahan kekusutan lebihan panjang. Sebarang aliran darah yang bersifat ganjil akan menyebabkan pembentukan thrombus dan mengurangkan jangka hayat RSVG itu sendiri.

A COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF PROLONGING SURVIVAL IN THE MICROVASCULAR VEIN GRAFTING

ABSTRACT

A digital artery disease in the upper extremity is uncommon to happen but the revascularization procedure is still needed. As action taken, the surgical vein bypassing or vein interposition is performed. However, one or more internal diameters of the applied Reverse Saphenous Vein Graft (RSVG) are blocked and severely narrowed due to the irregular geometry formation such as internal diameter mismatched and over the length kink after the revascularization. In previous researches, the irregular geometry formation, the size discrepancy and bent in the vessel caused the abnormal blood flow and initiated the thrombosis. Furthermore, their previous works were also supported by clinical theory.The objective of this study is to investigate the effect of the blood flow on internal diameter mismatched and over the length kink of the RSVG models that relates to their long term survival. A Three-Dimensional Computational Fluid Dynamic (3D CFD) method is employed to investigate the velocity, the pressure gradient and the Wall Shear Stress (WSS) on ideal straight and irregular geometry of the RSVG models. For this research, the pulsatile laminar blood flow demonstrates non-hydraulically flow in irregular geometry of the vein graft models compared to an ideal straight model even in a steady state laminar blood flow test. As a conclusion, the results showed high value in the velocity, the pressure gradient and the WSS in the mismatch problem but low value in the velocity, the pressure gradient and the WSS in the over length kink problem. Any abnormal blood flow behavior will initiate the formation of the thrombosis and reduce the vein graft survival.

CHAPTER 1

INTRODUCTION

1.1 Upper extremity vein grafting surgery

A formation of atherosclerosis in the upper extremity rarely happened compared to the lower extremity (Jocelynet al., 2007; P., Berg et al., 2007). It happens if an internal diameter of the blood vessel becomes narrow and will increase the stiffness of the blood vessel wall or decrease in the flexibility of the blood vessel. As action taken, the surgical vein bypassing or vein interposition is performed to several patients who suffer with arterial disease in order to overcome the blockage especially in the digital artery (Van & Guthrie, 1906; Raafat et al., 2006; Jocelyn, et al., 2007; Zol et al, 2007). In 1906, the first vein grafting has been successfully done by Van Carrel A. and Guthrie. Based on the literature reviews on the vein grafting surgical technique, the artery segment which affected the thrombosis was end-to-end removed, and the previously cut saphenous vein graft from the lower limb was reversely attached (David, L. Andrew, & Thomas, 2001; George et al., 2008). The most suitable veins are available at the dorsum of the foot and ankle or the forearm (H., Piza-Katzer, 1979; David et al., 2001).

One of the requirements is that the previously cut reversed saphenous vein graft (RSVG) should be closely similar in the length and internal diameter as previously removed artery segment (H., Piza-Katzer, 1979).Thus, the RSVG is suggested as an ideally applied for the vein grafting procedure. There are several reasons for this (H.,Piza-Katzer, 1979;C.M.,Grondin& R.,Limet, 1977; C.Minale et al., 1984; David, L. Andrew,& Thomas, 2001). First, the saphenous vein is plentiful and applicable in performing multiple graft procedure; second it is easily harvested; third, it has large diameter and fourth, it is reachable to any artery because it is long (Sabik, 2011).

1.1.1 Computational Fluid Dynamics Analysis

Several numerical techniques, especially the Computational Fluid Dynamics (CFD) has rapidly developed into a useful tool to obtain greater understanding of the fluid behavior even at the micro vessels (Tzu-Ching et al,. 2011). A Three-Dimensional Computational Fluid Dynamics (3D CFD) uses the Finite Volume Methods (FVM) to solve a huge number of equations such as the Navier-Stokes equation and to analyze problems that involve the blood circulation flow. This requires powerful computers to perform and handle a large number of equations and iterations in calculation. The accurate results from the complex simulations can be achieved in many difficult cases such as the investigation of the turbulence pulsatile blood flows in the artificial human heart. Advances in the CFD enable us to predict the blood flow pattern in the vein grafting surgery as well as the artificial part design.

The basic principle of the 3-D CFD modeling method is that the simulated flow region is divided into small mesh cells and formed the nodes; within each of nodes the flow is either kept under constant conditions or varied smoothly. The differential equations of momentum, energy, and mass balance are discretized and represented in terms of the variables at the center of or at any predetermined position within the cells. These equations are solved iteratively until the solution reaches the desired accuracy.