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Influence of Competitive Flow Caused by Different Stenosis on Coronary Artery Bypass Hemodynamics and PIV Study

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Abstract: Coronary heart disease (CHD) is one of the most common forms of heart disease, which means that coronary stenosis can cause insufficient blood supply to the heart and lead to coronary heart disease. Coronary artery bypass grafting (coronary bypass) is often used in the treatment of patients with coronary heart disease. After surgery, because the stenosis of the coronary artery is not completely occluded, the blood flow through it will compete with the blood flow of the graft, making it possible to transplant blood vessels. The blood flow is affected, reducing long-term permeability. When the coronary artery is completely stenotic, the distal blood flow is completely supplied by the graft; when the coronary artery is not completely narrow, the blood flow is supplied by the stenotic coronary artery and the graft vessel, thus creating a competitive relationship, the narrow crown The blood flow in the vein is considered to be a competitive flow, and different stenosis produces a competitive flow of different strengths. A highly competitive flow reduces blood flow in the graft and reduces graft life. On the other hand, at the anastomosis, due to the existence of competitive flow, abnormal blood flow occurs at the anastomosis, which causes local intimal hyperplasia of the blood vessel, leading to restenosis. The degree of stenosis is an important factor affecting the competitive flow. In order to study the influence of competitive flow under different stenosis conditions on the local area of bypass surgery, the numerical simulation and PIV experiments were used to analyze the effects of competitive flow on grafts and anastomosis. The ideal coronary artery stenosis model was established with 30%, 40%, 50%, 60%, 70%, 80%, 90%, and seven different degrees of stenosis. Numerical simulation uses finite element analysis software to determine the normal physiological boundary conditions for steady state analysis; PIV experiment establishes transparent silica gel model, using water flow as medium, water pressure as boundary condition to simulate competitive flow, and macroscopic flow field inside the bypass surgery site Steady-state flow studies were performed and the effects of competitive flow on bridging blood vessels and stenotic blood flow were analyzed. The ratio of the flow rate QC of the stenotic vessel to the flow rate of the bridge vessel flow QG is an index of the reaction competition. A ratio greater than 1 is considered to be a highly competitive flow. In the numerical simulation, the intensity of the competitive flow is less than 1 when the degree of stenosis is below 50%, indicating that the blood flow in the graft vessel is significantly lower than that in the stenotic coronary artery, which is a highly competitive flow, and the average wall in the entire graft vessel. The shear stress is less than 1 Pa. Many studies

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have found that wall shear stress is an important factor causing vascular lesions. Wall shear stress below 1 Pa will cause adaptive contraction of blood vessels, which is not conducive to the long-term effectiveness of grafts; the degree of stenosis is 80. At %-90%, eddy currents appear at the anastomosis, which easily causes anastomotic stenosis. In the PIV experiment, the overall flow velocity in the graft vessel increased by 50% with a narrowing degree as a dividing line, less than 50%, and the intensity of the competitive flow was higher at the time of stenosis, and the competition ratio was greater than 1. 70% of the stenosis. The phenomenon of eddy currents also occurs. The velocity flow diagram in the numerical simulation is basically similar to the flow field measured in the PIV experiment. The PIV experiment qualitatively verifies the result of numerical simulation. The 50% stenosis of the coronary artery is a transition point of a competitive flow, and less than 50% of the stenosis will result. Highly competitive flow affects blood flow in the graft vessel, which results in a lower average wall shear stress at the lower end of the graft vessel and is not effective for a long period of time; above 70% stenosis, eddy currents may occur at the anastomosis, which may This leads to stenosis at the anastomosis and restenosis of the stenotic coronary artery.

Keywords: Coronary artery bypass, stenosis degree, competitive flow, numerical simulation, PIV.