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Study on the Influence of Right Atrial Pressure on the Numerical Calculation of Fractional Flow Reserve

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Abstract: Coronary atherosclerotic heart disease, or coronary heart disease for short, is a heart disease caused by atherosclerotic lesions of coronary arteries, resulting in stenosis, spasm and live obstruction, leading to myocardial ischemia, hypoxia and even necrosis, and is the most common type of organ lesions caused by atherosclerosis. Coronary computed tomograph angiography (CCTA) has been the most effective method for examining coronary heart disease, but this method can only be judged from the morphology. It has been shown that when the coronary stenosis rate is as high as 70%, only 32% of blood vessels can cause myocardial ischemia. Therefore, there is no direct relationship between coronary stenosis and myocardial ischemia. Long-term clinical studies have shown that the determination of fractional flow reserve (FFR) is the gold standard for the current diagnosis of hemodynamic changes in coronary artery stenosis. FFR is invasive, expensive and technically demanding for operators, which greatly limits clinical use. FFR-CT, which is derived by CCTA and Computational fluid dynamics (CFD), is a new noninvasive method for assessing coronary stenosis. Initially, FFR was calculated by Myo=(pd-pv)/(pa-pv), where Pd (distal pressure) was stenosis, Pa (proximal arterial pressure) was stenosis, and Pv (venous pressure or right atrial pressure, RAP) was right atrial pressure. Since Pv is small, usually 4~8 mmHg, a simplified formula can be used for literature expenditure, namely, Myo=Pd/Pa. However, due to the small amount of clinical data, it is impossible to determine whether Pv has an influence on the calculation of FFR. Therefore, an ideal vascular model with a diameter of 3 mm, a stenosis length of 10 mm, and a stenosis degree of 40%, 50%, 60%, and 70%, respectively, was established. This study defines interface conditions and special coupling algorithms for 0D/3D coupling. ANSYS-CFX is used in 3d simulation, and the 0D model is calculated with Fortran subroutine based on CFX Junction Box. Data exchange between the 0D and 3D models is implemented using CFX User CEL Function. A constant pressure of 90 mmHg was applied at the model entrance, and a constant resistance Rmicro was provided at the outlet boundary to simulate the microcirculation resistance in the downstream hyperemia state. Pv was given at the resistance end, and the values were respectively 0 mmHg, 4 mmHg, 6 mmHg and 8 mmHg. Three cardiac cycles are calculated, and the cardiac cycle is 0.8 s. The calculation results of the last period are extracted after the result converges. It was calculated that when the stenosis degree was 40%, Pv was 0 mmHg, FFR=0.913; when Pv was 8 mmHg, FFR=0.921; the rate of change was 0.876%. When the degree of stenosis is 50%, Pv is 0 mmHg, FFR=0.87;

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when Pv is 8 mmHg, FFR=0.883; the rate of change is 1.49%. When the degree of stenosis is 60%, Pv is 0 mmHg, FFR=0.776; when Pv is 8 mmHg, FFR=0.799; the rate of change is 2.96%. When the degree of stenosis is 70%, Pv is 0 mmHg, FFR=0.579; when Pv is 8 mmHg, FFR=0.623; the rate of change is 7.60%. The results show that with the increase of Pv, the calculated value of FFR also increases; and as the degree of stenosis increases, the degree of influence of Pv deepens. In the actual situation, the patient's right atrial pressure is not 0 mmHg, so in order to improve the accuracy of FFR calculation, Pv should be taken into consideration, and the calculation formula should not be simplified.

Keywords: FFR, right atrial pressure, finite element calculation.

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