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Role of coronary CT imaging diagnosis of coronary functional stenosis

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Abstract: Coronary heart disease is a major disease harmful to human health, and coronary angiography, as the gold standard for the diagnosis of coronary heart disease, can directly observe the degree of coronary artery diameter stenosis. However, the invasive and expensive cost of coronary angiography limits its clinical application, and some studies have shown that coronary anatomical stenosis can not fully reflect the myocardial ischemia, and put forward the concept of functional stenosis. With the development of CT technology, coronary artery CT angiography has become a new method to detect functional stenosis. This paper reviews the role of coronary artery CT angiography in the detection of functional coronary artery stenosis.

1. Introduction

According to 'China cardiovascular disease report 2018' [1], the prevalence and mortality of cardiovascular disease in China are on the rise, and the estimated number of patients with coronary heart disease is about 11 million. The pathogenesis of coronary heart disease is due to coronary atherosclerotic plaque formation caused by stenosis, plaque instability rupture, arterial thrombosis and lumen occlusion leading to myocardial ischemia and necrosis in the corresponding blood supply area. Stable coronary heart disease is mainly caused by coronary artery stenosis caused by atherosclerosis, so it is speculated that detecting the degree of stenosis caused by atherosclerotic plaque can play an auxiliary role in the diagnosis of stable coronary heart disease. Coronary angiography (CAG), as the gold standard for the diagnosis of coronary heart disease, can make a clear diagnosis of the location, scope and severity of the lesions. However, interventional therapy guided by coronary angiography alone is not accurate. For patients with multiple coronary artery stenosis and moderate coronary artery stenosis, the compensatory effect of the cardiovascular system makes the anatomical stenosis of the coronary artery can not fully reflect the ischemia of the dominant myocardium [2], and CAG requires high technical requirements for operators, and may increase plaque damage and vessel wall damage during operation, resulting in serious complications. Therefore, the search for a non-invasive and inexpensive method to measure functional stenosis has become a research hotspot in recent years.

Hemodynamic study found that when there was no obvious stenosis, the coronary artery blood flow maintained the stability of the pressure of the blood flow conduction system from the proximal to the distal. The stenosis will cause the decrease of the distal pressure of the lesion, so the effect of

coronary artery stenosis on the degree of myocardial ischemia can be understood indirectly by measuring the change of coronary artery pressure. Pijils [3] proposed that the index of coronary blood flow can be calculated by measuring the change of pressure, that is, invasive non-invasive flow reserve fraction (FFR), which is defined as the application of vasoactive drugs to maximize the hyperemia and dilatation of coronary artery in the presence of coronary artery stenosis. The ratio of the maximum blood flow to the theoretical maximum blood flow in the myocardial area supplied by the stenotic coronary artery was measured by pressure guide wire. When there is no stenosis, the FFRCT value is 1.0. When FFR $\leq$ 0.75, it is generally considered that the stenotic coronary artery will cause myocardial ischemia, and when FFR $\geq$ 0.8, it is often considered that the stenotic coronary artery will not cause myocardial ischemia. The measurement of FFR in coronary angiography has been regarded as the gold standard for diagnosing whether revascularization is needed in the diagnosis of coronary functional stenos. At $0.75 < FFR \leq 0.8$, it is necessary to combine clinical and other related indexes to judge whether coronary artery revascularization is needed or not.

2. Coronary artery CT imaging

With the gradual popularization of multi-slice spiral CT in China, coronary artery CT angiography (CTTA) has the characteristics of non-invasive, simple operation, low cost and high repeatability, so it has become one of the effective means to detect coronary heart disease. Studies [4] have shown that the efficiency of multi-slice spiral CT in the detection of coronary artery stenosis is consistent with that of coronary angiography. According to the diagnostic results of coronary angiography, coronary artery CT angiography has high accuracy, sensitivity and specificity, and can effectively evaluate the degree of lumen stenosis and be used as a screening method for asymptomatic patients. But the false positive rate of CTTA is high [2].

3. CT non-invasive blood flow reserve score

The non-invasive flow reserve fraction of CT is a new method to evaluate coronary FFR without loading drug, additional scan and no additional dose [5]. FFRCT is based on high-quality CCTA image data to get the diameter and bifurcation of the coronary artery tree and other information. Assuming the blood flow or pressure value of an ascending aorta, according to the principle of hydrodynamics and Navier-Stokes equation, the ratio of the average pressure of the distal stenosis in the condition of maximum coronary artery congestion to the average pressure of aorta in the condition of maximum coronary artery congestion, namely FFRCT, is calculated.

3.1 Practical application of FFRCT

Heart Flow FFRCT [6] (California, USA) is a commercial analysis software. The FFRCT analysis of HeartFlow is a 3D full-order model, which has the characteristics of high degree of reduction and accuracy of intravascular blood flow, but it takes a large amount of computation, takes a long time to complete, and requires offline processing and remote transmission, which is limited to clinical use.

In recent years, researchers have developed a variety of FFRCT analysis software [7] based on different algorithm models. The results show that FFRCT has a high predictive value for functional stenosis. The cFFR software [8] developed by Siemens is a reduced-dimensional model of computational fluid dynamics, which reduces the amount of calculation and time (about 30 minutes). Now a new on-site FFR algorithm (uCT-FFR) based on CFD modeling developed by domestic researchers [9] shows that the sensitivity, specificity and accuracy of uCT-FFR in the diagnosis of functional stenosis are 89%, 91% and 91%, respectively. Its diagnostic efficiency is better than that of CCTA and coronary angiography.

3.2 Advantages and disadvantages of FFRCT in clinical decision-making

For some moderate stenosis, the diagnosis of CTTA and CAG is most likely to show myocardial mismatch dominated by anatomical stenosis. In the group of moderate stenosis (40%-69%) of DISCOVER-FLOW [10], the diagnostic accuracy and specificity of FFRCT were higher than those of CTTA (accuracy of 0.866, 0.56, specificity of 0.83, 0.26 respectively), moderate stenosis of DeFACTO [11] (30%-69%), accuracy of FFRCT based on blood vessels and patients were 0.79 and 0.81, respectively, while the accuracy of CTTA results was only 0.53, 0.50. There are studies to establish cost-benefit models based on DISCOVER-FLOW, FAME guidelines and PROSPECT research. The results showed that among the five ways of diagnosis and treatment, the cost of operation was the lowest when the degree of stenosis was more than 50% by CTTA detection and when the FFRICA result was more than 50% and the FFRCT value was more than 0.8. FFRCT still has some shortcomings. It has been reported [12] that when the FFRCT value is in the gray area (0.7-0.8), the diagnostic accuracy is only 61.2%. Outside the range, the accuracy of diagnosis and treatment is more than 85%.

4. Coronary artery technique

4.1 Parameters based on density attenuation in the lumen

Through the information of blood flow reflected by the change of contrast medium during CCTA, the researchers proposed a series of parameters reflecting the change of contrast medium [13], including the first proposed intraluminal density attenuation gradient TAG, the corrected intracavitary density gradient CCO, the combination of the two corrected intraluminal density attenuation gradient TAG-CCO, and intraluminal blood flow coding TAFE and contrast density difference CCD. The clinical effects of CCO and TAG are still controversial [13-15]. TAFE, combined with TAG, contrast agent arterial input time interval, average cross-sectional area and vascular length, confirmed that the calculated results of TAFE were in good agreement with the flow measured by CFD model [16]. CCD is defined as the CT value of the proximal lumen and the ratio of the CT value of the narrowest initial lumen to the transverse axial area of the lesion. Studies have shown that CCD is inversely proportional to FFR [17], which can better reflect the degree of functional stenosis. However, the diagnostic efficacy of CCD and TAFE clinical trials need to be further verified.

4.2 CTTA Quantitative indicator

Among the quantitative indexes of coronary artery stenosis, the maximum lumen area and the maximum area stenosis rate can independently predict coronary artery stenosis. In plaque characteristics, plaque area, plaque length, remodeling index, napkin ring sign and perivascular fat density index can independently predict functional stenosis [17]-[19]. Making use of the rapid development of machine learning in recent years and the combination of various quantitative indicators, it is expected to improve the diagnostic efficiency of CCTA in the diagnosis of functional stenosis.

5. Conclusion

For the diagnosis of stable coronary heart disease, coronary angiography can provide information about anatomical stenosis, which is the gold standard for the diagnosis of coronary heart disease. Compared with coronary angiography, coronary artery CT imaging is used in pre-screening of asymptomatic patients because of its non-invasive, simple operation, low cost and high repeatability.

FFRCT is based on high-quality CTTA image data and does not require additional load, additional scanning and additional dose. The diagnostic accuracy and specificity are higher than that of coronary artery CT imaging, but there is a grey interval that needs other functional methods for diagnosis. Coronary artery CT imaging quantitative index can independently predict coronary functional stenosis. Using the method of machine learning, combined with FFRCT, the parameters reflecting the changes of contrast medium in coronary artery CT imaging and the quantitative indexes of coronary artery CT imaging, it is expected to improve the effect of clinical diagnosis.

References

[1] Hu Shengshou, Yang Yuejin, Zheng Zhe, et al. Summary of Chinese Cardiovascular Disease report 2018 [J]. China Journal of Circulation, 2019: 209-220.

[2] Cheng Guanxun, Li Lei, Liu Guoshun, Yan Jing, & Yu Kanghui. (2014). Clinical diagnosis of coronary artery stenosis by dual source ct coronary angiography. Functional and Molecular Medical Imaging (Electronic version), 3 (001), 27-30.

[3] N. H. J. Pijls et al., "Fractional Flow Reserve Versus Angiography for Guiding Percutaneous Coronary Intervention in Patients With Multivessel Coronary Artery Disease", Journal of the American College of Cardiology, 2010, 56(3): 177-184.

[4] Xu Weihua. Evaluation of coronary artery stenosis and plaque stability in patients with coronary atherosclerotic heart disease by multi-slice spiral CT angiography [J]. Image Science and Photochemistry, 2020, v. 38 (03): 120,124.

[5] B. Murray K. Koo et al., "Diagnosis of Ischemia-Causing Coronary Stenoses by Noninvasive Fractional Flow Reserve Computed From Coronary Computed Tomographic Angiograms", J. Am. Coll. Cardiol., 2011, 58(19): 1989-1997.

[6] J. K.min et al., "non-invasive fractional flow reserve from coronary artery patients", Jacc: cardiovascular imaging, 2015, 8(10): 1209-1222.

[7] L. Yang et al., "Diagnostic performance of rapid non-invasive fractional flow reserve derived from coronary artery CT angiography: an initial validation study", Clinical Radiology, 2019, 74(12): 973.e1-973.e6.

[8] M. Kruk et al., "Workstation-Based Calculation of CTA-Based FFR for Intermediate Stenosis", JACC: Cardiovascular Imaging, 2016:9(6): 690-699

[9] Z-Q. Wang et al., "Diagnostic accuracy of a deep learning approach to calculate FFR from coronary CT angiography", p7.

[10] J. K. Min et al., "Usefulness of Noninvasive Fractional Flow Reserve Computed from Coronary Computed Tomographic Angiograms for Intermediate Stenoses Confirmed by Quantitative Coronary Angiography", Am. J. Cardiol., 2012, 110(7): 971-976.

[11] R. Nakazato et al., "Noninvasive Fractional Flow Reserve Derived From Computed Tomography Angiography for Coronary Lesions of Intermediate Stenosis Severity: Results from the DeFACTO Study", Circ. Cardiovasc. Imaging,. 2013, 6(6): 881-889.

[12] Mengmeng Yu et al., "study on the accuracy of FFR_ (CT) based on machine learning in the diagnosis of functional coronary artery stenosis", International Journal of Medical Radiology, 2018, 41(3): 282-286

[13] Mu Yue, Hong Ye, Han Tingting and Huang Minggang, "Research Progress of Coronary artery CT Angiography in the Evaluation of Coronary artery functional Stenosis", Progress in Cardiology, 2021,42(3): 211-215.

[14] C. Celeng et al., "Anatomical and Functional Computed Tomography for Diagnosing Hemodynamically Significant Coronary Artery Disease", JACC Cardiovasc. Imaging, 2019, 12(7): 1316-1325.

[15] M. J. Bom et al., "Diagnostic Value of Transluminal Attenuation Gradient for the Presence of Ischemia as Defined by Fractional Flow Reserve and Quantitative Positron Emission Tomography", JACC Cardiovasc. Imaging, 2019, 12(2): 323-333.

[16] S. G. Ahn et al., "Combination of the Thermodilution-Derived Index of Microcirculatory Resistance and Coronary Flow Reserve Is Highly Predictive of Microvascular Obstruction on Cardiac Magnetic Resonance Imaging After ST-Segment Elevation Myocardial Infarction", JACC Cardiovasc. Interv, 2016, 9(8): 793-801.

[17] D. Dey et al., "Integrated prediction of lesion-specific ischaemia from quantitative coronary CT angiography using machine learning: a multicentre study", Eur. Radiol., 2018, 28(6): 2655-2664.

[18] P. Yin et al., "Noninvasive Quantitative Plaque Analysis Identifies Hemodynamically Significant Coronary Arteries Disease", J. Thorac. Imaging, Volume Publish Ahead of Print, 2020: 1.

[19] P. L. von Knebel Doeberitz et al., "Coronary CT angiography-derived plaque quantification with artificial intelligence CT fractional flow reserve for the identification of lesion-specific ischemia", Eur. Radiol, 2019, 29(5): 2378-2387.