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Original Article

Analysis on clinical value of dual-source CT coronary angiography combined with SPECT in assessing correlation between myocardial perfusion abnormality and coronary artery stenosis

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Abstract: Objective: To assess the correlation of myocardial perfusion abnormality with coronary artery stenosis by virtue of dual-source CT coronary angiography combined with single-photon emission computed tomography (SPECT), and to investigate and discuss its clinical value. Methods: The clinical data of 96 patients with clinically suspected coronary heart disease were retrospectively analyzed. All the patients received dual-source CT coronary angiography and SPECT for myocardial perfusion imaging during hospitalization. In combination with the imaging results, Spearman correlation analysis was performed to study the correlation of coronary artery stenosis with myocardial perfusion abnormality, and the positive detection rate of dual-source CT coronary angiography combined with SPECT in coronary heart disease was analyzed. Results: A total of 288 branches of left anterior descending coronary artery (LAD), left circumflex coronary artery (LCx) and right coronary artery (RCA), which included 80 normal branches and 208 stenotic branches, were examined among the 96 patients with clinically suspected coronary heart disease through dual-source CT coronary angiography. Among them, there were 48 branches with a caliber of 1-25%, 56 branches with a caliber of 26-50%, 78 branches with a caliber of 51-75% and 26 branches with a caliber of >76%. The myocardia dominated by the abovementioned LAD, LCx or RCA were examined by SPECT myocardial perfusion imaging, and it was indicated that the perfusion was normal in 110 branches, mildly decreased in 42 branches, moderately decreased in 104 branches and severely decreased in 32 branches. It was seen by integrating the results of the above two types of imaging that the proportions of perfusion abnormality in the myocardia dominated by the coronary arteries with degrees of stenosis of 1-25%, 26-50%, 51-75% and >76% were 29.17%, 89.29%, 79.49% and 92.31%, respectively. Spearman correlation analysis manifested that the degree of coronary artery stenosis was positively correlated with the degree of myocardial perfusion abnormality (r=0.675, P=0.002). The positive detection rate of dual-source CT coronary angiography combined with SPECT in coronary heart disease was higher than that of dual-source CT coronary angiography (χ^2=7.705, P=0.006) or SPECT (χ^2=28.891, P=0.000) alone. Conclusion: The dual-source CT coronary angiography combined with SPECT can increase the diagnostic accuracy of coronary heart disease and objectively evaluate the relationship between different degrees of myocardial perfusion abnormality and coronary artery stenosis in patients with coronary heart disease, providing a theoretical basis for selection of clinical treatment protocols.

Keywords: Coronary heart disease, dual-source CT coronary angiography, single-photon emission computed tomography, myocardial perfusion abnormality, coronary artery stenosis

Introduction

In recent years, there is a fairly obvious trend toward increased incidence of coronary heart disease. However, a portion of patients with coronary heart disease receive inadequate or excessive treatment, which is closely related to the inaccurate evaluation [1]. Currently, coronary angiography is still regarded as one of the main methods for intuitively and accurately reflecting the degree of coronary artery stenosis and diagnosing coronary heart disease, but it has obvious trauma and high risk and fails to analyze the influence of coronary artery steno-

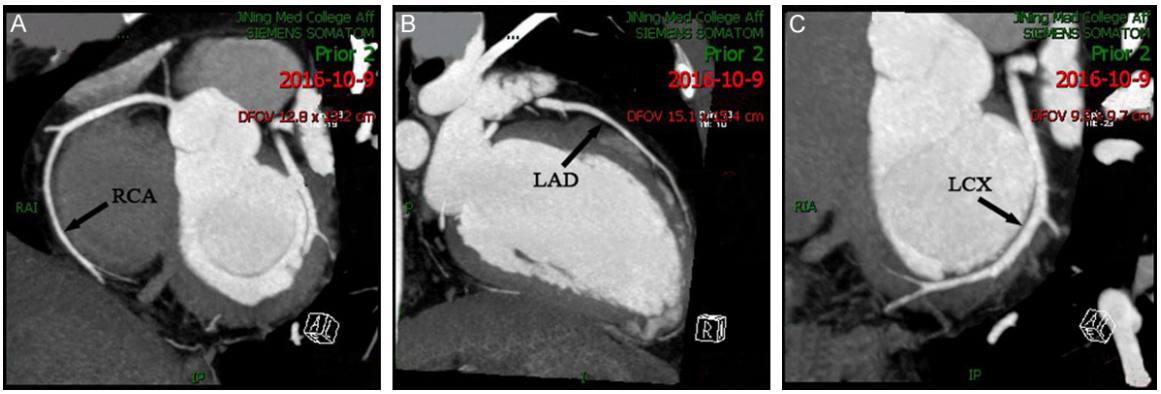

Figure 1. Image reconstruction via dual-source CT coronary angiography. CT, computed tomography; LAD, left anterior descending; LCx, left circumflex; RCA, right coronary artery. It was seen that the main branches of the coronary artery (LAD, LCx, RCA) were clearly displayed. There were plaques formed in the main branches of the coronary artery, but no obvious stenosis was observed. A: RCA; B: LAD; C: LCx.

sis on myocardial perfusion, so it is difficult to popularize coronary angiography as a routine screening method for coronary heart disease [2, 3]. A study revealed that for patients with suspected coronary heart disease who have no history of coronary heart disease, the coronary artery stenosis rate detected by coronary angiography does not exceed 40% [4]. Based on the above views, the application of noninvasive imaging examinations before coronary angiography has become a key link in improving the diagnostic efficiency of coronary heart disease. Both dual-source CT coronary angiography and single-photon emission computed tomography (SPECT) are recognized as reliable noninvasive imaging methods for detecting coronary heart disease in China and foreign countries, of which dual-source CT coronary angiography is applied more maturely and can evaluate whether coronary artery stenosis exists and assess the degree of stenosis accurately. However, it is difficult to evaluate the myocardial perfusion [5-7]. At present, myocardial perfusion imaging by means of SPECT is widely applied to assess myocardial perfusion and understand whether there is ischemia in myocardium dominated by stenotic coronary artery [8-10]. On basis of the advantages and disadvantages of the above two imaging examination methods, their combination can be utilized to diagnose the stenotic coronary artery causing abnormal myocardial perfusion. Whereas, there are few relevant studies, and no unified conclusion has been achieved yet. To this end, this study aims to analyze the clinical significance of dual-source CT coronary angiography combined with SPECT in assessing the correlation of myocardial perfusion abnormality with coronary artery stenosis.

Materials and methods

General data

The clinical data of 96 patients with suspected coronary heart disease who were admitted and treated in The Affiliated Hospital of Jining Medical University from January to December 2016 were retrospectively analyzed. All the patients underwent the dual-source CT coronary angiography and SPECT within 1 week after admission to The Affiliated Hospital of Jining Medical University. There were 66 males and 30 females aged 36-81 years old with an average of 58.23±5.64 years old, including 62 cases of hypertension, 52 cases of diabetes mellitus and 38 cases of hyperlipemia.

Inclusion criteria: 1) Patients with clinically suspected coronary heart disease, accompanied by varying degrees of chest tightness, shortness of breath, anterior-chest pain and other symptoms, or with a history of angina pectoris; 2) Patients with no allergic history of iodine contrast agent; 3) Patients with sinus rhythm or drug-controlled heart rate not more than 65 time/min; 4) Patients with no history of asthma, chronic obstructive pulmonary disease or other serious respiratory diseases, who could cooperate in breathing; 5) Patients with ST-T abnormalities in ECG and positive results in treadmill exercise test.

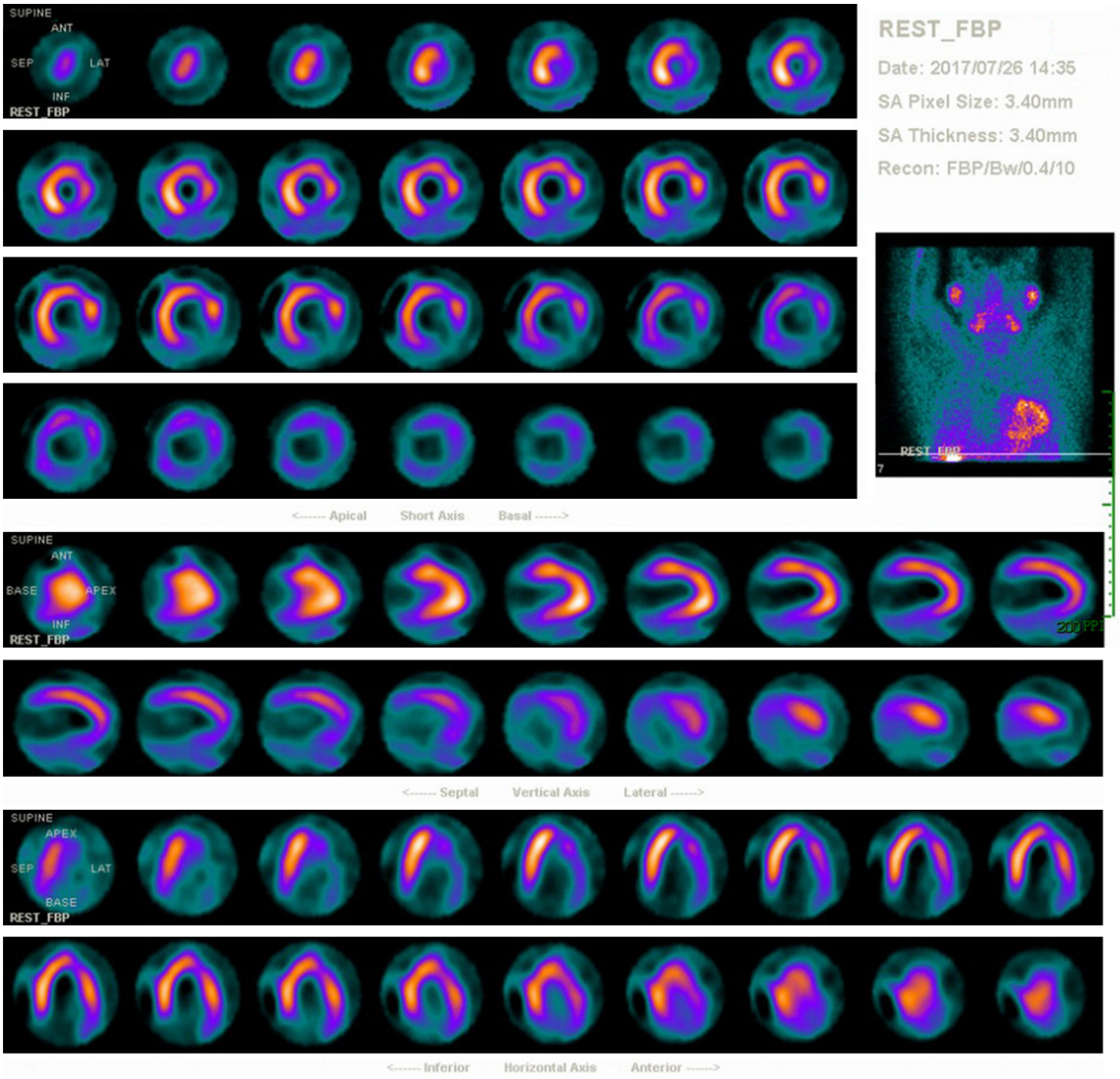

Figure 2. Images of myocardial perfusion imaging by SPECT. SPECT, single-photon emission computed tomography. The typical sectional image at the top right corner displays uneven distribution of the imaging agent, indicating that the myocardial perfusion is poor. There was even distribution of the imaging agent in other myocardial segments, with neat edges, indicating that the myocardial perfusion is good.

Exclusion criteria: Patients with arrhythmia; allergy to iodine contrast agent; renal insufficiency; congestive heart-failure; hypotension; sick sinus syndrome; or intolerance to intravenous injection by high-pressure injector.

This study was approved by the Ethics Committee of the Affiliated Hospital of Jining Medical University, and all the enrolled patients signed the informed consent.

Dual-source CT coronary angiography

All the patients received dual-source CT coronary angiography using the retrospectively ECG-gated trigger scanning method via SOMATOM Definition Flash CT (Siemens, Germany). Scanning range: from 1 cm below the tracheal carina to the diaphragmatic surface of the heart. A total of 70-80 mL contrast agent (omnipaque) was injected using a high-pressure injector from the elbow vein at a rate of 4-5 mL/s, and 50 mL normal saline was injected in the same way. The aortic root was chosen for small dose test at first to obtain the CT value, and automatic scanning was initiated after delay for 5-6 s. Scanning parameters are as follows: tube voltage: 120 kV, tube current: 380-400 mA, collimator width: 0.625*64 mm, viewing angle: 150*150 mm to 180*180 mm, single-loop rotation time: 350 ms, and cover-

Table 1. Analysis of dual-source CT coronary angiography results (branch)

Coronary artery type	LAD	LCx	RCA	Total
Normal	14	32	34	80
Stenosis degree				
1-25%	2	18	28	48
26-50%	22	18	16	56
51-75%	48	16	14	78
>76%	10	12	4	26
χ^2	17.154[a]	2.165[b]	37.555[c]	37.613[d]
P	0.000[a]	0.141[b]	0.000[c]	0.000[d]

Note: LAD, left anterior descending; LCx, left circumflex; RCA, right coronary artery. [a]Comparison between LAD and LCx; [b]comparison between LCx and RCA; [c]comparison between LAD and RCA; [d]comparison among the three groups.

Table 2. Analysis of myocardial perfusion imaging results (branch)

Coronary artery type	LAD	LCx	RCA	Total
Normal	22	42	46	110
Degree of myocardial perfusion				
Mild decrease	6	12	24	42
Moderate decrease	52	32	20	104
Severe decrease	16	10	6	32
χ^2	11.805[a]	2.277[b]	26.964[c]	27.312[d]
P	0.001[a]	0.131[b]	0.000[c]	0.000[d]

Note: LAD, left anterior descending; LCx, left circumflex; RCA, right coronary artery. [a]Comparison between LAD and LCx; [b]comparison between LCx and RCA; [c]comparison between LAD and RCA; [d]comparison among the three groups.

age area: 4 cm. The image was analyzed after scanning, the raw data were sent to an advanced workstation for processing, and the images were reconstructed via maximum intensity projection, multi-planar reconstruction and volumetric imaging (**Figure 1**).

The degree of coronary artery stenosis was assessed by two experienced physicians using the double-blind method, which was divided into 5 grades, namely, normal (stenosis degree <1%) and stenosis degrees of 1-25%, stenosis degrees of 26-50%, stenosis degrees of 51-75% and stenosis degrees >76%. Except for the group with stenosis degree <1%, the remaining four groups were regarded as positive coronary heart disease examination groups.

Myocardial perfusion imaging

All the patients underwent the myocardial perfusion imaging examination conducted by Symbia T6 SPECT instrument (Siemens), of which the imaging agent was $^{99}Tc^m$-methoxyisobutylisonitrile (MIBI), and the injected dose was 740 MBg. The myocardial perfusion imaging was performed at 1-1.5 h after the injection of the imaging agent, and 1 frame of image was collected every 6° for 30 s, of which the matrix was 64*64. Then the $^{99}Tc^m$-MIBI was injected under submaximal bicycle exercise test in 24 h later for stress myocardial imaging, during which the heart rates of the patients were controlled and the resting images were collected. The images were reconstructed via Butterworth filtered back projection to obtain images of different layers (**Figure 2**).

Two experienced physicians interpreted the images using the double-blind method and determined the areas of abnormal myocardial blood perfusion. With the maximum counting area of myocardium of left ventricle as the normal reference area, the myocardial perfusion was divided into 4 grades according to the coronary 17-segment scoring method of the American Heart Association: normal perfusion; mild decrease; moderate decrease and severe decrease. All the groups other than the normal group were regarded as positive coronary heart disease examination groups.

Methods of judging myocardial perfusion areas dominated by major coronary artery branches

The anterior wall, anterior septum, cardiac apex and anterolateral wall were determined as the left anterior descending coronary artery (LAD) perfusion areas, the posterolateral wall as left circumflex coronary artery (LCx) perfusion area, and the posterior septum and inferior-posterior wall as right coronary artery (RCA) perfusion areas. The stenotic coronary arteries that caused abnormal myocardial blood perfusion were matched according to the abovementioned two imaging results.

Table 3. Analysis of the correspondence between coronary artery stenosis and myocardial perfusion abnormality (branch)

Coronary artery stenosis	Normal	1-25%	26-50%	51-75%	>76%	Total
Degree of myocardial perfusion						
Normal	52	34	6	16	2	110
Mild decrease	18	10	8	2	4	42
Moderate decrease	10	4	30	56	4	104
Severe decrease	0	0	12	4	16	32
Abnormality ratio of perfusion (%)	35.00	29.17	89.29	79.49	92.31	61.81

Table 4. Distribution of positive prevalence in coronary artery branches detected by different methods (branch)

Inspection method	Normal	Positive	χ^2	P
Dual-source CT coronary angiography	80	208	7.068[a]	0.008[a]
SPECT	110	178	28.891[b]	0.000[b]
Joint inspection	52	236	7.705[c]	0.006[c]
Total			28.975[d]	0.000[d]

Note: SPECT, single-photon emission computed tomography. [a]Comparison between dual-source CT coronary angiography and SPECT; [b]comparison between SPECT and combined examination; [c]comparison between dual-source CT coronary angiography and combined examination; [d]comparison among the three groups.

Data processing

SPSS18.0 software was used for experimental data processing. Measurement data conforming to the normal distribution and homogeneity of variance were presented as mean ± standard deviation ($\overline{x}$ ± sd), and independent-samples t-test was performed for comparison between two groups. Chi-square test or Kruskal-Wallis H test was conducted for enumeration data, rank sum test was used for ranked data, and the correlation between variables was studied via Spearman correlation analysis. The threshold of significance was 0.05.

Results

Analysis of dual-source CT coronary angiography results

In this study, a total of 288 branches of LAD, LCx and RCA (including 80 normal branches and 208 stenotic branches) were examined among the 96 patients with clinically suspected coronary heart disease through dual-source CT coronary angiography. Among them, there were 48 branches with a caliber of 1-25%, 56 branches with a caliber of 26-50%, 78 branches with a caliber of 51-75% and 26 branches with a caliber of >76% (**Table 1**). There were significant differences in the degree of stenosis among the three groups of coronary artery branches (χ^2=37.613, P=0.000). In terms of pairwise comparisons, the difference in the stenosis degree was statistically significant between LAD and LCx (χ^2=17.154, P=0.000) and between LAD and RCA (χ^2=37.555, P=0.000), but it was not statistically significant between LCx and RCA (χ^2=2.165, P=0.141), indicating that the degree of stenosis in LAD was the highest.

Analysis of myocardial perfusion imaging results

It was discovered through SPECT myocardial perfusion imaging on myocardia dominated by the abovementioned LAD, LCx and RCA that the perfusion was normal in 110 branches, mildly decreased in 42 branches, moderately decreased in 104 branches, and severely decreased in 32 branches (**Table 2**). The differences in the degree of myocardial perfusion were significant among the three groups of coronary artery branches (χ^2=27.312, P=0.000). The analyses of pairwise comparisons manifested that the difference in the degree of myocardial perfusion was statistically significant between LAD and LCx (χ^2=11.805, P=0.001) and between LAD and RCA (χ^2=26.964, P=0.000), but it was not statistically significant between LCx and RCA (χ^2=2.277, P=0.131), indicating that the degree of myocardial perfusion was decreased most in LAD.

Analysis of combined imaging results

It was revealed by integrating the results of the above two types of imaging that the proportions of perfusion abnormality in the myocardia controlled by the coronary arteries with stenosis degrees of 1-25%, 26-50%, 51-75% and >76% were 29.17%, 89.29%, 79.49% and 92.31%, respectively. Spearman correlation analysis displayed that the degree of coronary

artery stenosis was positively correlated with the degree of myocardial perfusion abnormality (r=0.675, P=0.002). See **Table 3**.

Analysis of advantages of examination combining dual-source CT coronary angiography with SPECT

The results of dual-source CT coronary angiography indicated that the groups with coronary artery stenosis of 1-25%, 26-50%, 51-75% and >76% were deemed as positive groups for coronary heart disease examination, and the results of SPECT showed that the groups with mildly, moderately and severely decreased degree of myocardial perfusion were taken as positive groups for coronary heart disease examination. If there was a positive examination result in one of the methods, it would be determined that it was a positive coronary heart disease group for dual-source CT coronary angiography combined with SPECT. There were significant differences in the positive detection rates of coronary heart disease among the three groups of examination methods (χ^2=28.975, P=0.000). The analyses of pairwise comparisons revealed that the difference in the positive detection rate of coronary heart disease was statistically significant between dual-source CT coronary angiography and SPECT (χ^2=7.068, P=0.008), between dual-source CT coronary angiography and combined examination (χ^2=7.705, P=0.006), and between SPECT and combined examination (χ^2=28.891, P=0.000), indicating that the differences in the positive detection rate of coronary heart disease was statistically significant among the three groups, and that the positive detection rate of coronary heart disease was the highest by means of dual-source CT coronary angiography combined with SPECT (**Table 4**).

Discussion

Considering that the degree of coronary artery stenosis in patients with coronary heart disease has no linear positive correlation with the degree of abnormal myocardial perfusion, if single anatomical imaging or functional imaging technique is adopted, the coronary artery lesions will be reflected from only one level, such as anatomical lesions or functional lesions, resulting in excessive or inadequate treatment. Since the scanning speed, imaging quality and radiation dose of dual-source CT coronary angiography are further optimized, the coronary artery stenosis and calcification can be displayed clearly, and the efficiency of dual-source CT coronary angiography in evaluating the existence of coronary artery stenosis and the stenosis degree is comparable to that of coronary angiography, so it is widely recognized in clinic [11]. However, dual-source CT coronary angiography is incapable of obtaining the information about myocardial perfusion and determining whether the perfusion in myocardia dominated by stenotic coronary artery branches is good or not, and it is more difficult to assess the survival of myocardial cells. According to the above situations, SPECT was adopted in this study to evaluate the cardiac function of patients before and after treatment according to the abnormal myocardial perfusion, thus guiding the coronary angiography and interventional therapy. The myocardial perfusion imaging by virtue of SPECT plays a key role in diagnosing suspected coronary heart disease and assessing therapeutic effect and prognosis. At present, a number of studies have confirmed that myocardial ischemia induced by cardiac load is an important factor for predicting the patients' poor prognosis. It was pointed out in a study on evaluation of myocardial perfusion by means of SPECT myocardial perfusion imaging that the incidence rate of major cardiovascular events in patients with excellent myocardial perfusion does not exceed 2% [12]. On basis of the above viewpoints and overall advantages and disadvantages of dual-source CT coronary angiography and SPECT, the two kinds of imaging techniques are combined to complement each other's advantages. In this retrospective study, dual-source CT coronary angiography was applied to assess the degree of coronary artery stenosis, and SPECT was utilized to assess the degree of myocardial perfusion abnormality, so as to analyze the correlation between coronary artery stenosis and myocardial perfusion abnormality, which was conducive to improving the diagnostic efficiency of coronary angiography and guiding treatment.

This study revealed that the degree of coronary artery stenosis was positively correlated with the degree of myocardial perfusion abnormality in most patients with suspected coronary heart disease, that is, the degree of myocardial perfusion abnormality was aggravated with the

increasing degree of coronary artery stenosis, which is identical to the research viewpoints of most scholars. However, some studies have demonstrated that the degree of coronary artery stenosis has no association with the degree of myocardial perfusion abnormality in a minority of patients with coronary heart disease, which may be related to the fact that only three larger branches of coronary artery (LAD, LCx and RCA) were enrolled in this study, which have overlapping blood-supply sites [13, 14]. In this study, the results of dual-source CT coronary angiography indicated that 4 patients with coronary artery stenosis of 1-25% had moderately and severely decreased myocardial perfusion as well as larger range of myocardial defects. There were 10 cases with negative results of dual-source CT coronary angiography but positive results of SPECT myocardial perfusion imaging. The main reason might be the fact that the microcirculation disturbance in the abnormal myocardial perfusion area is associated with coronary artery spasm [15]. Among various noninvasive imaging examinations for coronary heart disease, SPECT is widely applied and accepted, which is of great significance in evaluating the risk classification of coronary heart disease and predicting the occurrence of long-term adverse cardiac events. Li et al. conducted a long-term follow-up study for more than 8 years and discovered that in the process of prognostic evaluation and treatment guidance for patients with coronary heart disease on basis of the SPECT myocardial perfusion imaging results, the average annual mortality rate of patients with severe abnormality of myocardial perfusion is significantly higher than that of patients with normal imaging [16]. Matsuo et al. studied and revealed that in patients with suspected coronary heart disease and abnormal SPECT myocardial perfusion imaging, the possibility of major serious adverse cardiac events is remarkably higher than that in patients with normal imaging [17]. Similarly, the research of Zhao et al. demonstrated that SPECT myocardial perfusion imaging could assess the myocardial perfusion abnormality, which contributes to evaluating the prognosis of patients and predicting serious complications [18].

Coronary heart disease patients with coronary artery stenosis >50% often have multiple stenotic coronary artery branches, in which the concordance rate of diagnosis through dual-source CT coronary angiography combined with SPECT is higher. However, the degree of coronary artery stenosis in a portion of patients is not consistent with that of myocardial perfusion abnormality. The reason for the above circumstances in this study was related to the coronary artery stenosis resulted from calcified plaque. Current studies believe that the stability of coronary calcified plaque is better than that of other types of plaque, mainly because the formation of coronary calcified plaque needs a long time, and collateral circulation is formed easily, which is conducive to compensatory formation of declined myocardial perfusion induced by the coronary calcified plaque. Abnormal myocardial perfusion exists in some patients with the degree of coronary artery stenosis of 26-50%, and the site of stenotic coronary artery is basically corresponding to that of abnormal myocardial perfusion. It has also been reported that the coronary artery stenosis of 50% is regarded as the critical value for the diagnosis of coronary heart disease, while that of less than 50% is defined as the negative perfusion result [19, 20]. Nevertheless, it could be seen from this study that there was still myocardial perfusion abnormality in coronary heart disease patients with coronary artery stenosis of less than 50%, and most of these patients had unstable plaques which leads to abnormal myocardial perfusion, resulting in significantly higher risk of acute coronary events than that of patients with stable plaques. Therefore, it is believed that even if mild abnormality is presented on the SPECT myocardial perfusion imaging, clinical intervention is still required in time due to the poor stability of plaque.

The combined results of the above two types of imaging in this study indicated that the proportions of perfusion abnormality in the myocardia dominated by the coronary arteries with stenosis degrees of 1-25%, 26-50%, 51-75% and >76% were 29.17%, 89.29%, 79.49% and 92.31%, respectively. The correlation coefficient of the degree of coronary artery stenosis with degree of myocardial perfusion abnormality was 0.675 (P=0.002), suggesting that the degree of coronary artery stenosis has a positive correlation with the degree of myocardial perfusion abnormality, which is beneficial to formulation of further diagnostic protocols. The

coronary heart disease patients with a degree of coronary artery stenosis of >76% should actively receive interventional therapy. For patients with a coronary artery stenosis degree of 51-75%, in combination with the results of SPECT myocardial perfusion imaging, it is necessary to conduct interventional therapy if there is abnormal myocardial perfusion. As for the degree of stenosis of 26-50%, in case of normal or mildly decreased myocardial perfusion and stable plaque, it is allowable to only perform medicine intervention instead of interventional therapy. In terms of coronary heart disease patients with coronary artery stenosis of 1-25%, it was indicated in the results of this study that there were still 10 cases of mildly decreased myocardial perfusion and 4 cases of moderately decreased myocardial perfusion. Moreover, among the patients without coronary artery stenosis, there were also 18 patients with mildly decreased myocardial perfusion and 10 patients with moderately decreased myocardial perfusion. Such phenomena may be associated with coronary artery spasm. As a result, the myocardial function of the patients cannot be assessed completely in accordance with the stenosis degree in the coronary angiography, and the myocardial perfusion needs to be judged in combination with the SPECT. For coronary heart disease patients with normal coronary artery or coronary artery stenosis of 1-25%, if the myocardial perfusion is decreased, clinical observation will to be enhanced, and medicine intervention will be conducted according to their clinical situations.

However, the small sample size in this retrospective study might lead to slight fluctuations in relevant coefficients, there was a lack of follow-up survey results, and the correlation between the degrees of coronary artery stenosis assessed by dual-source CT coronary angiography and the degree of myocardial perfusion abnormality detected by SPECT was not analyzed from the perspective of prognosis. In future research, therefore, it is necessary to increase the sample size, conduct the prospective study and improve the research program.

In conclusion, the degree of coronary artery stenosis assessed by dual-source CT coronary angiography is positively correlated with the degree of myocardial perfusion abnormality detected by SPECT. The results of this study suggested that the dual-source CT coronary angiography combined with SPECT could increase the diagnostic accuracy of coronary heart disease and objectively evaluate the relationship between different degrees of myocardial perfusion abnormality and coronary artery stenosis in patients with coronary heart disease, providing a theoretical basis for selection of clinical treatment protocols.

Disclosure of conflict of interest

None.

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