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Myocardial Perfusion Imaging Versus Coronary CT Angiography for the Detection of Coronary Artery Disease

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Abstract

Background: Considering the importance of early diagnosis of coronary artery disease (CAD) in reducing subsequent complications, non-invasive tests, especially myocardial perfusion imaging (MPI) and coronary CT angiography (CCTA) play a pivotal role in this regard. Therefore, a study was conducted to compare the diagnostic results of these two methods.

Methods: A cross-sectional study was conducted on 51 patients who underwent MPI and CCTA and 18 patients whose noninvasive test was positive and high risk underwent invasive coronary angiography (ICA) at Farshchian Heart Center, Hamadan, Iran, during one year (2019-2020). The data including demographic characteristics as well as the histories of dyslipidemia, smoking, positive family history, hypertension, and diabetes, was collected using a checklist. Descriptive statistics, independent samples t-tests, and chi-square tests and Sensitivity, Specificity and Positive predictive value, Negative predictive value and Roc Curve were applied for data analysis. For data analysis, the SPSS software version 21 was used. P values less than 0.05 were considered

Results: The mean age of the patients, including 29 males (56.9%) and 22 females (43.1%), was 60.11±8.99 years. No significant correlation was found between the results of MPI and CCTA compared to ICA. CCTA demonstrated higher sensitivity (100% versus 88%), higher specificity (33% versus 0%), and higher accuracy (66% versus 44%) than MPI. Furthermore, CCTA performed better in terms of positive predictive value (60% versus 47%) than MPI. The overall diagnostic accuracy of MPI when CCTA is considered as a reference, according to the area under the Rock's curve, which is equal to 0.691, is relatively good. Based on the calculated optimal Yoden index, the appropriate cut point is SSS≥8. on the other hand, MPI can be useful in functional evaluation and has important rules in moderate stenosis.

Conclusion: Considering the high sensitivity and accuracy of CCTA compared to MPI, CTCA, and MPI provide differing information for CAD from respective angles. The correlation between CTCA and MPI is supplemental rather than substitutional.

Keywords: Coronary artery disease, Myocardial perfusion imaging, SPECT, Invasive coronary angiography, Coronary CT angiography

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Introduction

Cardiovascular disease (CVD) is the leading cause of death in many countries, including Iran, and the most important cause of disability. Despite diagnostic and therapeutic advances, one-third of the patients presenting with

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↑What is "already known" in this topic:
Coronary artery disease (CAD) is a leading cause of death and disability. Non-invasive methods like MPI offer functional insights, while CCTA accurately depicts coronary anatomy but lacks functional or prognostic details.

→What this article adds:
CCTA showed higher sensitivity and accuracy than MPI in this study. The two methods complement each other in evaluating CAD. Combining MPI and CCTA improves diagnostic performance and aids CAD management decisions. CCTA had 100% sensitivity in detecting CAD, compared to 88% for MPI, and identified cases that MPI missed.

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myocardial infarction (MI) die, and the remaining two-thirds that survive never recover fully (1, 2). Different factors are involved in the development of CAD. Some of them like sex, age, and genetics, are unmodifiable, while some other factors like diabetes, hypertension, obesity, smoking, hypercholesterolemia, a lack of physical activity, mental pressure, and stress, are modifiable. The objective of many studies is to find a method for the diagnosis of CAD before it is symptomatic and to determine the prevalence of possible risk factors; therefore, invasive and non-invasive diagnostic methods like exercise treadmill test (ETT), stress echocardiography, myocardial perfusion imaging, and angiography are used to diagnose CAD (3). The cost and risk of invasive angiography have encouraged the development of new diagnostic methods that allow the coronary arteries to be visualized non-invasively. The last decade has seen great strides in the field of cardiac imaging, particularly in the ability of CCTA to visualize the coronary lumen with sufficient diagnostic accuracy. Evidence has emerged to support the role of CCTA as an alternative noninvasive, anatomic diagnostic imaging modality. CTCA reflects the anatomical morphology of the coronary arteries without directly providing functional or prognostic information on CAD. That is to say, it does not directly provide the pathophysiological significance correlated with the coronary lesions (4). As the extent and severity of ischemia are the key factors for deciding whether to select revascularization or medical therapy for CAD, a non-invasive evaluation of the anatomical and functional information on the coronary lesions prior to performing CAG becomes unnecessary, and reasonable requirement. MPI using single photon emission Computer Tomography (SPECT)is a well-established, non-invasive method that has beenwidely used for decades to provide functional informationon coronary lesions. Numerous studies have proven that MPIis a cost-effective, non-invasive method for CAD management (5-7).

Since it has been used in the clinic for so long, MPI is a well-known and well-documented non-invasive cardiac imaging technique for the diagnosis, prognosis, and risk stratification of CAD. MPI is incredibly effective, has guided significance, and has a better cost-benefit ratio for patient management, according to several findings from evidence-based medical studies (6, 8). As a result, interventional therapy is typically not necessary. Several class I indications for MPS in the risk assessment of individuals with an intermediate or high chance of CAD have been developed as a result of numerous study findings (9, 10).

Combined CTCA and SPECT MPI should have positive incremental values and play a complementary role in CAD management by revealing the coronary arteries anatomy and its relative functional significance stenosis, factors that are extremely important for the decision-making process and for improving the cost-effectiveness with regard to CAD therapy. Moreover, studies that compared the results of CCTA and ICA reported the high diagnostic accuracy of CCTA in the diagnosis of CAD (11, 12).

There are debates regarding the specificity and sensitivity of MPI. Since MPI is a non-invasive method, the evaluation of the advantages of this method is of great importance in prioritizing the diagnostic methods for the diagnosis of cardiovascular lesions, especially in determining the risk of CAD (13). Therefore, the aim of the present study was to evaluate the diagnostic value of MPI compared to CCTA in patients who underwent both procedures in the Farshchian Heart Center Hospital, Hamadan, Iran. The results of ICA were used as the gold standard method with which the results of CCTA and MPI were compared using specificity and sensitivity.

Methods

Study population

This cross-sectional study included a total of 54 consecutive patients with known or suspected CAD.Within 60 days, CTCA, MPI, and CAG were performed on every case. However, the order of CTCA and MPI varied depending on the particular clinical situation. CAG was next conducted. The study's participants had an average age of 60.11 ± 8.99 years, and 29 of them were women (56.9%). The following conditions were excluded from the study: patients having bypass grafts, unstable angina, acute coronary syndrome (ACS), often premature heartbeats, atrial fibrillation, X syndrome, significant coronary calcification, and motion artifacts impacting the measurement of the stenoses. The study was approved by the ethical committee of the Hamadan University of Medical Science and all of the patients supplied written informed consent.

CTCA

After taking the patient's history regarding sensitivity to the contrast medium and asthma and GFR calculation, imaging was done using a 128-slice Multidetector CT Scanner (SOMATOM Definition AS, Siemens AG). About 80-90 mL of non-ionic iso-osmolar contrast medium (Visipaque 320mg/ml) was injected via the antecubital vein at a rate of 5ml/s followed by 40 mL normal saline. Oral metoprolol was prescribed for patients with a heart rate of more than 60 beats/minute. Imaging was done from the carina to the diaphragmatic apex. Before injecting the contrast medium, calcium scoring was done using a slice thickness of 3 mm semiautomatically. CCTA images were obtained with a slice thickness of 3 mm and reconstructed with a slice thickness of 0.6 mm using the retrospective gated ECG triggering method. Then, the images obtained in coronal and sagittal planes as well as MIP and MPR reconstruction images, were evaluated. Segments with more than 70% luminal narrowing were considered as severe stenosis, indicating a positive result. In segments with severe calcification, it was regarded as obstructive coronary artery disease.

MPI

MPI with gated SPECT was done with Tc99M-Sestamibi using a Siemens machine. The scan was done in two parts (stress and rest) over two days. For the stress phase, treadmill exercise testing or pharmacological stress testing, as per the protocol of the center, is recommended. The scan was interpreted qualitatively by the nuclear med-

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icine specialist, and perfusion findings were quantified using the QPS software and reported as SRS, SSS, or SDS. The functional data were extracted using the QGS software and reported as wall thickness, wall motion, left ventricular end-systolic volume (LVESV), left ventricular end-diastolic volume (LVEDV), and left ventricular ejection fraction (LVEF). The myocardial regions supplied by the main coronary arteries were compared in terms of myocardial perfusion abnormalities (intensity and reversibility) in the stress and rest phases. The available reports of ischemia were determined according to vascular territories, and SSS≥1 was considered abnormal and low risk (positive result).

ICA

One-third of the patients underwent ICA in the present study. Conventional coronary angiography was carried out in accordance with established clinical standards. An expert cardiologist visually interpreted all coronary angiograms. The gold standard for the detection of CAD was a stenosis of 50% or more narrowing of the luminal diameter of the left main or 70% or greater narrowing of the other arteries.

Statistical analysis

Descriptive statistics, independent samples t-tests, and chi-square tests and Sensitivity, Specificity and Positive predictive value, Negative predictive value, and Roc Curve were applied for data analysis. For data analysis, the SPSS software version 21 was used. *P* values less than 0.05 were considered.

Results

Patient characteristics: The basic characteristics of the participants are presented in Table 1. According to Table 2, the mean age and BMI of the subjects with negative and positive MPI results were 60.42 years and 26.62 kg/m^2 and 60.60 years and 27.10 kg/m^2, respectively. The independent samples t-test revealed no statistically significant difference in mean age and BMI between subjects with positive and negative MPI results. Table 3 presents the distribution of gender, diabetes, hypertension, dyslipidemia, history of smoking, and a positive family history of CAD according to the MPI results. Chi-square showed no significant difference in the results of MPI in this regard (P>0.05).

According to Table 4, the mean age and BMI of the subjects with negative and positive CCTA results were 59.20 years and 27.01 kg/m^2 and 61.94 years and 27.09 kg/m^2, respectively. The independent samples t-test revealed no statistically significant differences in mean age or BMI between subjects with positive and negative CCTA results. The distribution of gender, diabetes, chronic hypertension, dyslipidemia, history of smoking, and a positive family history of CAD according to the CCTA results is presented in Table 5. Chi-square showed no significant difference in the results of CCTA in this regard (P>0.05). Table 6 presents the min, max, mean, and standard deviation of SSS, SDS, LVEDV, LVESV, and LVEF factors in 51 patients who underwent MPI.

Table 7 compares the diagnostic concordance between MPI and CCTA with ICA. No significant relationship was found between the results of CCTA and MPI in comparison with ICA as the gold standard diagnostic method (P>0.05).The sensitivity, specificity, and accuracy of

Table 1. Clinical characteristics of participant patients

Parameter	Overall (n=51)
Gender (F/M)	29/22
Age, mean ± SD	60.11 ± 8.99
Body mass index, mean ± SD (kg/m^2)	27.04 ± 1.67
Risk factors for CAD	
Diabetes	19 (37.3)
Hypertension	22 (43.1)
Dyslipidemia	17 (33.3)
Current Smoking	17 (33.3)
Family History	15 (29.4)

Table 2. Age and BMI distribution in patients with positive and negative MPI

Variable	MPI	Mean	*P*-value
Age (years)	Negative	60.42	0.950
	Positive	60.06	
Body mass (kg/m^2)	Negative	26.62	0.491
	Positive	27.10	

Table 3. Clinical Risk Factors in Patients with MPI Findings

Characteristic	MPI Positive (Mean)	MPI Negative % (Mean)	*P*-value
Gender			
Male	37.3	5.9	0.987
Female	49	7.8	
Diabetes			
Yes	35.3	2	0.176
No	51	11.8	
Hypertension			
Yes	35.3	7.8	0.421
No	51	5.9	
Dyslipidemia			
Yes	29.4	3.9	0.774
No	56.9	9.8	
Smoking			
Yes	34.1	2	0.250
No	54.9	11.8	
Family History			
Yes	21.6	7.8	0.083
No	64.7	5.9	

Table 4. Age and BMI distribution in patients with positive and negative CCTA

Variable	MPI	Mean	*P*-value
Age (years)	Negative	59.20	0.258
	Positive	61.94	
Body mass (kg/m^2)	Negative	26.62	0.861
	Positive	27.10	

Table 5. Clinical Risk Factors in patients with CCTA findings

Characteristic	CCTA positive (Mean)	CCTA negative (Mean)	*P*-value
Gender			
Male	15.7	27.5	0.689
Female	17.6	39.2	
Diabetes			
Yes	17.6	19.6	0.101
No	15.7	47.1	
Hypertension			
Yes	15.7	27.5	0.689
No	17.6	39.2	

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Table 6. The Frequency of MPI Findings in Patients

Variable	n	Min	Max	Mean	SD
SSS	51	0	16	6.18	3.95
SRS	51	0	6	1.02	1.76
SDS	51	0	10	5.16	2.8
LVEDV	51	45	85	56.33	6.95
LVESV	51	16	34	22.25	4.35
LVEF	51	50	70	60.18	6.02

Table 7. Comparison diagnostic concordance of MPI and CTA with ICA

Variable	Grouping	n (%)	*P*-value
MPI/ICA	MPI^+, ICA^+	8 (44.4)	0.303
	MPI^+, ICA^-	9 (50)	
	MPI-, ICA+	1(5.6)	
CTA	CTA+/ICA+	9 (50)	0.058
	CTA+, ICA-	6 (33.3)	
	CTA-,ICA-	3 (16.7)	

CCTA and MPI compared to ICA (gold standard) in 18 patients who underwent all three procedures are shown in Table 8. The sensitivities of CCTA and MPI were 100% and 88%, respectively.

The comparison of diagnostic test results of MPI and CCTA is shown in Table 9. If the results of MPI were considered as a reference criterion, the positive predictive value for a positive CT angiography test that can predict the presence of hemodynamic disorder is 88.2%, but the negative predictive value for rejecting perfusion disorders is relatively low (7.14%).

Pie charts A and B in Figure 1 show that among patients with positive MPI, 34.1% and 65.9% had positive and negative CCTA results, respectively also among patients with negative MPI, 71.4% and 28.6% had positive and negative CCTA results, respectively. Pie charts A and B in Figure 2 show that among patients with positive CCTA results, 88.2% and 11.8% had positive and negative MPI results, respectively also among patients with negative CCTA results, 14.7% and 85.3% had negative and positive MPI results, respectively.

Table 8. Diagnostic accuracy of CTA and MPI in the detection of CAD vs ICA as gold standard

Imaging Modality	MPI	CTA
True positive	8	9
True negative	0	3
False positive	9	6
False negative	1	0
Sensitivity (%)	88%	100%
Specificity (%)	0%	33%
Accuracy (%)	44%	66%
Positive predictive value (%)	47%	60%
Negative predictive value (%)	0%	100%

Sensitivity, Specificity, and Positive predictive value, Negative predictive value and Roc Curve

Table 9. Comparing the results of perfusion scan and CT angiography diagnostic tests

CTA Results	MPI Results		
	Positive	Negative	Total
Positive	5	29	34
Negative	2	15	17
Total	7	44	51

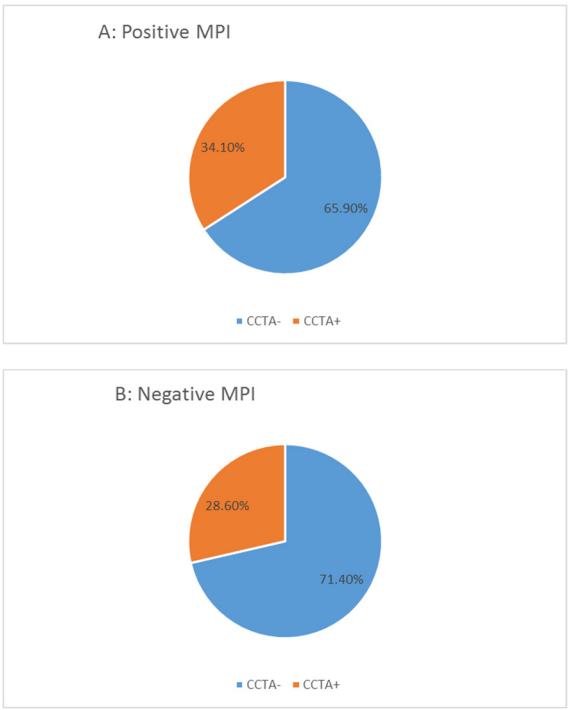

Figure 1. Pie charts show the percentage of positive or negative CCTAand MPI results among subjects with positive or negative CCTA and MPI results

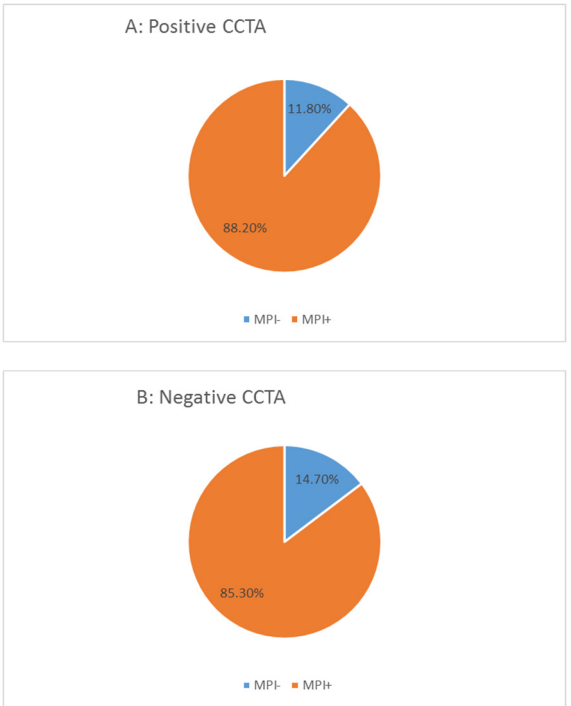

Figure 2. Pie charts show the percentage of positive or negative cardiac perfusion imaging (MPI) results among subjects with positive or negative CCTA results.

Roc curve analysis and calculation of the area under the roc curve (AUROC) was used to determine the overall diagnostic accuracy of MPI, considering CCTA as the reference (Figure 3).

The overall diagnostic accuracy of MPI, considering CCTA as the reference, was relatively good (AU-

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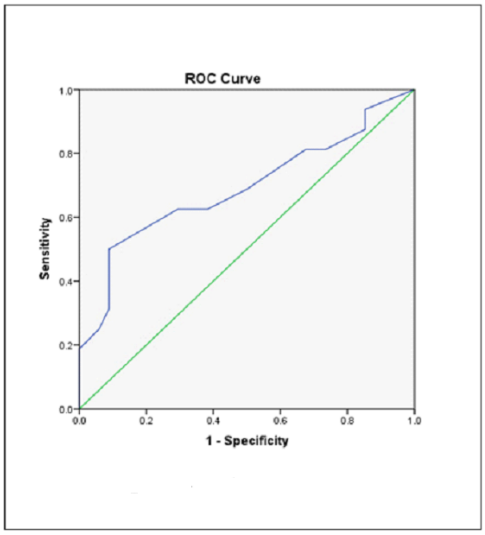

Area	Std.Error	*P*-Value
0.0691	0.089	0.021

Figure 3. RUC curve of MPI

Table 10. Calculation of Yoden's index of MPI cut-off points based on SSS when CCTA is considered as a reference

Cut-off	Sensitivity	Property-1	Yoden's Index
2.5	0.785	0.853	1.01
3.5	0.813	0.735	1.08
4.5	0.813	0.676	1.14
5.5	0.688	0.500	1.19
6.5	0.625	0.382	1.24
7.5	0.625	0.294	1.33
8.5	0.5	0.088	1.41
9.5	0.313	0.088	1.23
10.5	0.250	0.059	1.19
13.5	0.188	0.000	1.19
15.5	0.125	0.000	1.13

ROC=0.691). ROC curve analysis is also used to determine the most appropriate cut-off value in a diagnostic test. In this method, the sensitivity and specificity are calculated for all points, and the point with the maximal summation of sensitivity and specificity values is determined. The point with the highest "sensitivity" and the lowest "1-specificity" is considered as the cutoff point. Table 10 shows the Youden's index for different cutoff points, indicating that the highest value of the Youden's index was observed at a cutoff point of 8.5. A cutoff point of SSS=8.5 was associated with a "1-specificity" of 0.088 and "sensitivity" of 0.50, i.e. maximum summation of these two values according to SSS.

Discussion

In CAD patients, accurate non-invasive evaluation of ischemia and its extent and severity of CAD can be helpful in preventing invasive procedures and angiography. CCTA and MPS provide complementary information and are recommended for CAD evaluation according to different guidelines. The present study was conducted to compare the diagnostic accuracy of these two diagnostic modalities (14).

In the present study, there is no statistically significant difference in the results of MPI and CCTA based on the variables of gender, age, body mass index, history of diabetes, hypertension, dyslipidemia, history of smoking, and history of positive family, which shows the strength of these diagnostic tests and when interpreting the images, there was enough skill and precision to diminish the interfering factors. This part of our study was consistent with the study of Megna et al., who performed on 104 patients and did not observe a difference in basic clinical characteristics (15).

Statistical analysis of the data by chi-square test revealed that there was no statistically significant difference between the results of MPI and CCTA when compared to ICA (as the gold standard) (P<0.05). This finding is also consistent with the conclusion of the study by Lyu et al., which was conducted on 504 patients in China in 2012 (16).

In this study, the sensitivity of CCTA and MPI were estimated to be 100% and 88%, respectively, and these values were found in the multicenter study of Arbabzadeh et al. in 2015 on 391 patients in the United States, Germany, Japan, and Brazil were carried out and they were equivalent to 92% and 62% for CCTA and MPI, respectively .In the study of Arbabzadeh et al., the specificity of diagnos-

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tic tests of CT angiography and perfusion scan was estimated at 75% and 68%, respectively, and in the present study, these values were equal to 33% and 0% for CCTA, and MPI respectively (17).

Considering MPI as the reference criterion, a positive CCTA had a positive predictive value of 88.2% for the prediction of hemodynamic instability while its negative predictive value was relatively low (14.7%) for rejection of perfusion abnormalities. Circles A and B in Figure 1 show that among patients with positive MPI results, 34.1% and 65.9% had positive and negative CCTA results, respectively. Moreover, among subjects with negative MPI results, 71.4% had negative and 28.6% had positive CCTA results. Circles A and B in Figure 2 show that among patients with positive CCTA results, 88.2% had positive and 11.8% had negative MPI results. Moreover, among patients with negative CCTA results, 14.7% and 85.3% had negative and positive MPI results, respectively.

In the largest study comparing CCTA findings with those of rubidium-82-PET, CCTA was associated with defects in MPI, although the magnitude of this association was moderate. In the CCTA method, the worse the coronary stenosis, which is divided into less than 50%, 50-70%, and more than 70%, the positive predictive value (PPV) per patient is 29, 44, and 77 % respectively. On the contrary, the negative predictive value (NPV) for excluding myocardial ischemia was very high and was 92, 91 and 88%, respectively. Similarly, using FFR in 79 patients with CAD with stable symptoms, less than half of the lesions with 50% or more stenosis on CCTA had a significant pressure difference on both sides of the coronary stenosis. Overall, these findings were consistent with other studies and raised the concern that CCTA findings may lead to higher rates of coronary angioplasty and revascularization.

ROC curve analysis and calculation of the area under the roc curve (AUROC) were used to determine the overall diagnostic accuracy of MPI, considering CCTA as the reference (Figure 3). The overall diagnostic accuracy of MPI, considering CCTA as the reference, was relatively good (AUROC=0.691). ROC curve analysis is also used to determine the most appropriate cut-off value in a diagnostic test. In this method, the sensitivity and specificity are calculated for all points, and the point with the maximal summation of sensitivity and specificity values is determined. The point with the highest "sensitivity" and the lowest "1-specificity" is considered as the cutoff point. Table 10 shows the Youden's index for different cutoff points, indicating that the highest value of the Youden's index was observed at a cutoff point of 8.5. A cutoff point of SSS=8.5 was associated with a "1-specificity" of 0.088 and "sensitivity" of 0.50, i.e., the maximum sum of these two values according to SSS.

Conclusion

Both MPI and CCTA have good performances in detecting CAD. CTCA and MPI provide differing information for CAD from respective angles. Thus it is difficult to directly compare CTCA with MPI as they show different things. The correlation between CTCA and MPI is supplemental rather than substitutional. Using combined CTCA and MPI may markedly increase the diagnostic performance for the detection of CAD compared to CTCA alone, which may provide comprehensive information and play a significant role in the decision-making process for CAD management.

Authors' Contributions

Dr Farnaz Fariba was involved in the conception and design of the study, including the literature review, data collection, analysis, and interpretation, and also drafted the manuscript. Seyed Kamaledin Hadei, Hossein Forughi Moghadam, Maryam Alvandi were involved in the conception and design of the study, including data analysis and interpretation, and also review and evaluation of the manuscript. Other authors were involved in the study design and conduction. All authors reviewed the manuscript critically and approved the final manuscript.

Ethical Considerations

The study was conducted in compliance with ethical principles – patients were examined after obtaining informed consent.

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Conflict of Interests

The authors declare that they have no competing interests.

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