Original article

Correlation of myocardial perfusion SPECT with invasive and computed tomography coronary angiogram

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KEYWORDS

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Ischaemia
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ABSTRACT

Background: The consequences of atherosclerosis can be detected by multislice computed tomography (MSCT), invasive coronary angiogram (CAG) and the resultant myocardial ischaemia by myocardial perfusion single photon emission computed tomography (MPS). In this study an attempt is made to compare MSCT with MPS and also to compare the MSCT findings with that of invasive CAG in patients suspected to have coronary artery disease (CAD).

Materials and methods: A total of 99 patients suspected to have CAD underwent both MSCT and MPS with ^{99m}Tc sestamibi. The MSCT studies were classified as having no CAD, significant CAD (>50% diameter stenosis), and insignificant CAD (<50% diameter stenosis). Myocardial perfusion single photon emission computed tomography was reported as normal and reversible ischaemia. In a subgroup of 33 patient invasive CAG was done.

Results: In 99 patients, 396 coronaries were evaluated with MSCT and MPS. Coronary artery calcium scoring (CACS) in these patient ranged from 0 to 2200. No CAD was noted in 128 (32%) coronaries but MPS was found abnormal in 9 (7%) coronaries. Insignificant CAD was noted in 169 (43%) coronaries amongst which reversible ischaemia was noted in 23 (14%). Significant CAD was noted in 99 (25%) coronaries of which only 54 (55%) were MPS positive for reversible ischaemia. The MSCT has a negative predictive value (NPV) of 97%. When MSCT was normal, MPS was almost normal, but the reverse was not true. That is when MPS was normal MSCT was not always normal but showed lesion of insignificant obstruction.

In the subset of 33 patients, who underwent invasive angiogram, 132 coronaries were evaluated. Coronary angiogram showed 48 coronaries (36%) to have significant CAD (>50% diameter stenosis). Multislice computed tomography correlated well in 46 (84%) with *P* value of <0.001 (χ^2 -test) but for 9 (16%) showing overestimation due to increased CACS (>800). Myocardial perfusion single photon emission computed tomography was normal in 15 (27%) coronaries.

Conclusion: Myocardial perfusion single photon emission computed tomography provides functional information of the anatomical lesions and MSCT provides anatomical information. Both are two different diagnostic modalities. The MSCT has high NPV in patients with less likelihood for CAD. When compared with CAG, the correlation with MSCT was good and is useful where the calcium score is low.

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Introduction

It is a known fact that coronary artery disease (CAD) tends to occur at an early age in Indians. It is believed to be more severe and extensive in this group and follows a malignant

course.¹ Cross-sectional studies in Indians also documented a prevalence of CAD which is several fold higher than the prevalence in developed countries.² Projections based on the Global Burden of Disease study³ estimated that by year 2020 the burden of atherosclerotic cardiovascular disease in India will surpass any other geographical region in the world. Studies in Indian migrants in various parts of world have documented increased predisposition to CAD in comparison with the native population in these regions.

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The choice of treatment in patients with CAD stems from integration of both the extent and the severity of anatomic disease and the functional significance of the coronary lesions. Coronary arteries were studied by conventional coronary angiogram (CAG) invasively whereas the presence or absence of ischaemia is studied non-invasively with myocardial perfusion SPECT (MPS). Various imaging modalities are available to assess these with advantages and limitations. Multislice computed tomography (MSCT) allows good quality images non-invasively. Earlier studies comparing SPECT and MSCT shows some discrepancies between the anatomic extent of CAD and resultant ischaemia⁴ which is multifactorial. This leads to subjecting the patient for invasive CAG. The decision regarding revascularisation goes by the patient's symptoms and the severity of inducible ischaemia.⁵ This limited accuracy of MSCT in predicting physiologic significance would lead to an added non-invasive imaging with MPS, before considering revascularisation. Therefore we studied the relationship between the severity of anatomic CAD based on 64 slice MSCT, invasive CAG and the perfusion abnormalities by MPS.

Materials and methods

Study population

This prospective study included 99 consecutive patients between October 2005 and March 2007 who had either signs or symptoms suggestive of CAD are asymptomatic patients with risk factors, referred by physician for MPS and 64 slice MSCT as a part of work up of CAD. Patients with elevated serum creatinine (>1.5 mg/dL) and known case of obstructive CAD were excluded. Asymptomatic patients were studied if they had one or more risk factors for CAD which included diabetes mellitus (fasting blood levels of >126 mg/dL), hypertension (systolic pressure of >140 mmHg, diastolic pressure of 90 mmHg), dyslipidaemia (serum total cholesterol of 200 mg/dL or serum low-density lipoprotein (LDL) cholesterol of >130 mg/dL or serum triglyceride >150 mg/dL), history of smoking, body mass index (BMI >25 kg/m²) and strong family history of CAD or sudden coronary death.

Evaluation by myocardial perfusion single photon emission computed tomography

After informed consent, patients were administered with eight mCi of Tc-99m sestamibi intravenously at rest. The SPECT imaging was done 60 minutes post-injection by Siemen's ECAM, a dual head variable angle gamma camera with low-energy parallel hole collimator. After 4 hours of rest injection 24 mCi of Tc-99m sestamibi was administered at target heart rate for patients age (85% of maximal heart rate) of Bruce or modified Bruce protocol on tread mill exercise test. Exercise end points included physical exhaustion, angina, dysrhythmias, and exercise induced hypotension. Anti-ischaemic medications were discontinued 48 hours before MPS. Heart rate

and blood pressure were recorded at the beginning and at regular intervals during the treadmill test. Twelve lead electrocardiograms (ECGs) were recorded at intervals of 3 minutes and up to 6 minutes post-exercise. Stress Tc-99m sestamibi SPECT was initiated 60 minutes post-injection of the isotope.

The MPS studies were performed on dual headed scintillation camera using 76° acquisitions, 64 projections at 20s per projection. For Tc-99m sestamibi a 15% window centred on the 140KeV peak was used, and images were obtained in supine position. Gated SPECT was performed obtaining 8 frames/cycle for 180 with continuous step and shoot method from 45 right anterior oblique to 45 left posterior oblique. Images were acquired using 64×64 pixel matrix. Siemens cardiac SPECT reconstruction software programme was used to reconstruct the images. A standard filtered back-projection using Butterworth filter order five was utilised. Short axis (axial), horizontal long axis (coronal) and vertical long axis (sagittal) images were obtained.

The images were interpreted by two experienced independent observers without the knowledge of MSCT results. A perfusion abnormality showing complete filling up was considered to represent ischaemia. A perfusion abnormality that remained unchanged was regarded as fixed defect or scar and was excluded from the study. Where there was no demonstrable perfusion abnormality, the study was regarded as normal.

Evaluation by multislice computed tomography

An informed consent was taken. Patient with history of severe allergic reaction to contrast material and those with impaired renal function (serum creatinine level of >1.5 mg/dL) were not included in the study. To ensure the diagnostic image quality, target heart rate of <65 beats/min was attained during image acquisition. The patient's heart rate was measured during a breath holding test to determine whether the administration of a beta-blocker was necessary; and wherever indicated patient received iv 5–20 mg of metoprolol before the MSCT unless there was contraindication to its use.

To determine contrast agent transit time a total of 15 mL of the contrast, immediately followed by 40 mL of saline was injected at the flow rate of 5 mL/sec. Scanning was initiated 10 seconds after the start of the contrast injection. Axial images were acquired at the level of the aortic root (10/mm collimation) at intervals of 2 seconds by Toshiba 64 slice CT and were instantly displayed. Scanning was terminated when sufficient contrast enhancement of the aortic root was detected. The time interval from the initiation of the contrast injection to the peak opacification of the ascending aorta represented the contrast transit time.

Images were acquired in helical mode during injection of 60–100 mL of the contrast, with the exact amount depending on the duration of scanning, followed by 40 mL of saline at a rate of 4–5 mL/sec.

Images were reconstructed using retrospective electrocardiographic gating and the half scan reconstruction technique. Images were typically reconstructed with 0.75 mm section thickness and 0.4 mm overlap at 64 slice multidetector.

The images were interpreted by two experienced independent observers without the knowledge of the results of MPS and invasive coronary angiogram. The narrowing of luminal diameter of <50% was considered as insignificant CAD and >50% as significant.

Evaluation by invasive coronary artery disease

After informed consent, 33 of the 99 patients were taken up for invasive coronary angiogram (Philips Medical flat imaging system) using either transfemoral or transradial approach in various projections at the discretion of the cardiologist. All angiograms were reported by two different experienced cardiologists who were not aware of the MSCT and MPS results. The narrowing of luminal diameter of <50% was considered as insignificant CAD and >50% as significant.

Statistical analysis

All the variables were expressed as mean±standard deviation. The observations were expressed in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy. A χ^2 -test was used to assess the association between the two variables. A *P* value <0.05 was considered statistically significant.

Results

Of the 99 patients there were 79 males and 20 females, mean age of 55.4±9.4 years. Clinical characteristics of the study population are given in the Table 1.

Myocardial perfusion SPECT

All our patients were stressed on a treadmill. The end point was either 85% of maximum targeted heart rate, angina or

ECG changes. Abnormal perfusion findings were seen in 86 (22%) coronaries.

Multislice computed tomography

The CACS of these patients (*n*=99) ranges from 0 to 2000. According to MSCT evaluation of the 396 coronaries, significant CAD was observed in 99 (25%) coronaries. Insignificant CAD was noted in 169 (43%) coronaries and no CAD was seen in 128 (32%) coronaries.

Invasive coronary angiogram

A subset of 33 patients underwent invasive coronary angiogram. Vessel wise 132 coronaries were evaluated. Significant CAD was observed in 48 (36%) coronaries, 45 (34%) coronaries showed insignificant CAD and the rest 39 (30%) coronaries were normal.

Results of myocardial perfusion SPECT versus multislice computed tomography

Insignificant CAD was noted in 169 (43%) coronaries on MSCT of which, perfusion abnormalities were noted in 23 (14%) vessels. Of the 99 (25%) coronaries with significant CAD by MSCT, only 54 (55%) vessels showed perfusion abnormalities by MPS and 45 (45%) coronaries showed no perfusion abnormalities in spite of significant CAD in MSCT. In 128 (32%) coronaries though there was no CAD, MPS was abnormal in 9 (7%). Whenever MSCT was negative, MPS was almost negative. Whereas when MPS was negative, CAD could not be excluded. The NPV for MSCT was very high at 97% whereas MSCT could not predict ischaemic changes in a significant number of coronaries. The results of 396 coronaries evaluated on MPS and clinical trial application (CTA) are given in Table 2.

Results of myocardial perfusion SPECT versus multislice computed tomography versus coronary angiogram

Of the 132 coronaries, CAG and MSCT showed significant stenosis in 48 (36%) and 55 (42%) coronaries, respectively.

Table 2

Results of 396 coronaries evaluated on myocardial perfusion SPECT and clinical trial application.

Diagnosis	MSCT	MPS	
		Negative	Positive
Normal	128 (32%)	119 (93%)	9 (7%)
Insignificant CAD	169 (43%)	146 (86%)	23 (14%)
Significant CAD	99 (25%)	45 (45%)	54 (55%)

CAD: coronary artery disease, MPS: myocardial perfusion SPECT, MSCT: multislice computed tomography.

Table 1
Patients demographic data.

Gender (male/female)	79/20
Age	55.4±9.4
Risk factors for CAD	
Diabetes mellitus	64 (64.6%)
Hypertension	47 (59.5%)
Hyperlipidaemia	90 (90.9%)
History of smoking	35 (35.4%)
Family history of CAD	38 (38.3%)
BMI (>25 kg/m ²)	68 (68.6%)
Symptoms	
Asymptomatic	41 (41.4%)
Dyspnoea	7 (7.5%)
Atypical chest pain	35 (36.0%)
Angina pectoris	15 (15.1%)

BMI: body mass index, CAD: coronary artery disease.

Table 3

Results of 132 coronaries evaluated on myocardial perfusion SPECT, multislice computed tomography and coronary angiogram.

Diagnosis	CAG	MPS		MSCT	MPS	
		Positive	Negative		Positive	Negative
Normal	39 (30%)	6 (15%)	33 (85%)	38 (29%)	6 (19%)	32 (81%)
Insignificant CAD	45 (34%)	11 (24%)	34 (75%)	39 (30%)	11 (28%)	28 (72%)
Significant CAD	48 (36%)	40 (83%)	8 (17%)	55 (41%)	40 (73%)	15 (26%)

CAD: coronary artery disease, CAG: coronary angiogram, MPS: myocardial perfusion SPECT, MSCT: multislice computed tomography.

Table 4

Sensitivity, specificity, and accuracy of myocardial perfusion SPECT.

Gold standard test	CAG/MPS (%)
Sensitivity	87
Specificity	80
Accuracy	83

CAG: coronary angiogram, MPS: myocardial perfusion SPECT.

MPS showed ischaemia in 40 (73%) of 55 coronaries on MSCT but CAG showed 40 (83%) of 48 coronaries.

The sensitivity and specificity of MPS was 87% and 80%, respectively when compared with CAG.

The sensitivity, specificity of MSCT was 96% and 89%, respectively when compared with CAG. When the observations of MSCT was correlated with CAG (vessel to vessel), 46 of the 55 coronaries with significant CAD matched with CAG, still 11 did not correlate, that was due to the overestimated reporting of lumen narrowing on MSCT because of high CACS (>800). The accuracy rate of MSCT was high at 92%. The comparative results of 132 coronaries evaluated on MPS, CTA and CAG are given in Tables 3–5.

Discussion

In the present study MPS was compared with MSCT and both these non-invasive imaging modalities compared with that of invasive CAG on a vessel to vessel basis.

Myocardial perfusion SPECT versus multislice computed tomography

The incidence of abnormal MPS increased with detection of significant CAD in MSCT. But all were not haemodynamically significant. Forty-five percent of the coronaries in the group detected to have significant CAD and 86% (Table 2) of the coronaries in the group detected to have insignificant CAD on MSCT showed no perfusion abnormalities on MPS. Luminal narrowing does not always result in ischaemia. When MPS was normal, it did not exclude CAD because MSCT showed evidence for CAD. The mismatch in the results obtained shows that these two investigations were two different modalities complementing each other. Our observations are in accordance to the earlier report by Schuijff et al.⁶ who had studied 114 patients with intermediate likelihood of CAD. They showed 55% of the coronaries (obstructive and non-obstructive) were

Table 5

Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of CTA.

Gold standard test	CAG/MSCT (%)
Sensitivity	96
Specificity	89
PPV	85
NPV	97
Accuracy	92

CAG: coronary angiogram, MSCT: multislice computed tomography, NPV: negative predictive value, PPV: positive predictive value.

normal on MPS. Only 45% of patients with abnormal MSCT had perfusion abnormalities on MPS. The authors concluded that both provided complementary information on CAD. Similar observations were reported by Hacker et al.⁴ and Rippler et al.⁷ These authors concluded that combination of MSCT and MPS were non-invasive procedures to study comprehensively the anatomical and functional status of the coronary arteries. Giovanni Lucignani⁸ in his review discussed in depth about the role of MSCT and MPS and also with other modalities and was of the similar opinion. Studies published⁹ by authors on CACS for atherosclerosis burden on MSCT showed similar observations concluding that normal MPS does not exclude CAD but was of great importance in management and risk stratification.

Myocardial perfusion SPECT versus coronary angiogram

From our study the sensitivity and specificity of MPS to detect flow limiting stenosis were 87% and 80%, respectively (Table 4). This was consistent with the ACC/AHA/ASNC revised guidelines¹⁰ which showed the sensitivity and specificity from 33 studies to be 87% and 73%, respectively. The low specificity is due to factors affecting endothelial function, platelets, other coagulation factors, oestrogen levels, sympathetic tone and inflammatory processes that may affect the functional integrity of coronary plaques¹¹ and these factors govern the pathophysiology of ischaemia (Figure 1).

Coronary angiogram versus multislice computed tomography

Multislice computed tomography was analysed with invasive CAG, 46 (84%) of the coronaries with invasive CAG (*P* value

Figure 1 (A) Myocardial perfusion SPECT (MPS): Significant provokable ischaemia of apex, septum and posterolateral wall. Mild provokable ischaemia of anterior wall. (B) CT angiography (CTA): Coronary artery calcium scoring (CACS) PF 389, calcified plaques in proximal left anterior descending (LAD) causing 80–90%. Soft and calcified plaques in second OM causing 70–80% stenosis. (C) Coronary artery (CA): LAD proximal 95% occlusion and 100% occlusion after DI, OM2 90% occlusion. OM: obtuse marginal.

of <0.0001) (Figure 2), Nine (16%) of the coronaries did not correlate and the degree of narrowing was over estimated (Table 3). The overestimated luminal narrowing was due to the high CACS (>800) indicating the limitations of MSCT, but the accuracy was high.

We observed that the sensitivity, specificity, PPV, NPV, and accuracy rates for MSCT was 96%, 89%, 85%, 97%, and 92%, respectively with respect to invasive CAG (Table 5).

The NPV of MSCT was high. These findings were sustained by the previous reports by Schuijff et al. and Hacker et al.^{4,6,12}

Halon et al. studied 111 patients with 40-slice CT and compared with invasive CAG. They estimated a sensitivity, specificity and NPV of 84%, 87%, and 61%, respectively. Their NPV was very low.^{13,14} They concluded on the contrary to the above observations that MSCT would not replace the invasive coronary angiography in a routine clinical setting. Bax et al.¹⁵ in a pooled analysis of nine studies comparing MSCT and CAG showed a more sensitivity and specificity of 91% and 96%; however they concluded that this level of accuracy does not alter the value of MPS in the evaluation of CAD.

Figure 2 (A) Myocardial perfusion SPECT (MPS): Provocable ischaemia of anterior wall and apicoinferior wall. (B) CT angiography (CTA): Coronary artery calcium scoring (CACS) of 9, soft plaque in proximal LAD. (C) Coronary artery (CA): normal. CAG: coronary angiogram, LAD: left anterior descending, LMCA: left main coronary artery.

Conclusion

Myocardial perfusion single photon emission computed tomography and MSCT are two different non-invasive modalities. Myocardial perfusion single photon emission computed tomography shows haemodynamic significance of the anatomical lesion detected on MSCT and CAG thereby plays a larger confirmatory role in planning revascularisation. The MPS also plays a major role in patients whose calcium scores are high as the MSCT has got low specificity in them.

In patients with less likelihood for CAD, a normal MSCT can exclude CAD. The presence of CAD on MSCT indicates the need for MPS to assess the haemodynamic significance of the observed lesions. This additional information would help in planning treatment strategies.

A normal MPS excludes ischaemia but not CAD. Inclusion of MSCT would provide information on the burden of

atherosclerosis in the absence ischaemia. Abnormal MPS and MSCT warrant invasive coronary angiogram MSCT and MPS are non-invasive procedures and provide complementary information. MSCT and MPS can be repeated as and when necessary and are helpful in early detection of atherosclerotic burden before onset of symptoms, that is the preclinical atherosclerosis.

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