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Impact of combined supine and prone myocardial perfusion imaging using an ultrafast cardiac gamma camera for detection of inferolateral coronary artery disease

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ABSTRACT

Background: Although combined supine and prone acquisitions improve the detection of inferolateral obstructive coronary artery disease (CAD), the predictors of inaccurate detection of inferolateral ischemia have not been reported by using cadmium zinc telluride (CZT) myocardial perfusion imaging (MPI).

Methods and results: Vasodilator stress ^{99m}Tc tetrofosmin MPI using CZT camera and coronary angiography was performed in 322 patients within an interval of 2 months. Prone MPI was performed immediately after supine MPI. Narrowing of the luminal diameter ≥75% was considered significant. The presence of an abnormality on both supine and prone images was considered significant. Combined supine and prone imaging, compared with supine-only quantification, was more specific (93% vs. 72%, respectively, $p < 0.0001$) and accurate (88% vs. 74%, $p < 0.0001$) without compromising sensitivity (82% vs. 68%, $p = 0.10$). The area under the curve for detecting inferolateral ischemia was 0.769 (95% CI 0.705–0.833) for supine imaging and 0.802 (95% CI 0.730–0.875) for combined supine and prone imaging ($p < 0.05$). Multivariable analysis revealed that previous inferolateral myocardial infarction was an independent predictor of a false diagnosis (odds ratio = 3.45, 95% confidence interval [CI] 1.62–7.37, $p < 0.001$).

Conclusions: Combined supine and prone quantitative CZT MPI enhances the detection of inferolateral CAD without adversely affecting its sensitivity. However, we recommend inferolateral ischemia be monitored in patients with a history of previous inferolateral MI because previous inferolateral MI is a predictor of inaccurate diagnosis.

1. Introduction

Myocardial perfusion imaging (MPI) has traditionally been performed in most nuclear cardiology laboratories using standard dual detector single photon emission computed tomography (SPECT) cameras with patients in the supine position. Frequently, however, diaphragmatic attenuation of the inferolateral wall in these images causes false positive inferolateral wall defects that reduce test specificity [1,2]. Although combined supine and prone acquisitions improve the detection of obstructive coronary artery disease (CAD) in the inferolateral territories, the prolonged imaging time may preclude its routine use in clinical practice [3]. Furthermore, to date, the predictors of inaccurate detection of inferolateral ischemia have not been reported.

Discovery NM 530c nuclear imaging system (GE Healthcare, Haifa, Israel) has a new, highly efficient cardiac camera based on a multi-pinhole design with cadmium zinc telluride (CZT) pixelated detectors. The use of CZT detectors potentially improves image quality while significantly shortening image acquisition times and reducing isotope doses [4–7]. The purpose of the present study was to determine if combined supine and prone CZT SPECT imaging is more accurate than supine imaging alone in identifying inferolateral CAD without affecting specificity and to evaluate the factors of inaccurate detection of inferolateral ischemia.

2. Methods

2.1. Study population, CZT SPECT scanner and imaging method

The study group comprised 322 consecutive patients referred for SPECT MPI with suspected stable angina pectoris who also underwent angiography within an interval of 2 months.

Discovery NM 530c is equipped with a multi-pinhole collimator and 19 stationary CZT detectors that simultaneously capture 19 cardiac views. Patients were imaged in the

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supine position with arms raised over the head. Automated heart positioning in the quality field-of-view was determined by using real-time persistence imaging. Penalized maximum likelihood iterative image reconstruction adapted to the system's three-dimensional geometry was used to create transaxial slices of the left ventricle. No correction for scatter or attenuation was performed [8].

All patients underwent a 1-day ^{99m}Tc tetrofosmin adenosine stress and rest imaging protocol in accordance with published guidelines [9,10]. Pharmacological stress was induced by adenosine infused at a dose of 140 μg/kg/min. ^{99m}Tc tetrofosmin (370 MBq) was injected after 3 min of induced stress and image acquisition was performed 45 min later with the patient in supine followed immediately by imaging of the patient in a prone position. Rest MPI was then performed using the same acquisition protocol after injection of a 2-fold higher dose of ^{99m}Tc tetrofosmin (740 MBq). The duration of image acquisition was 5 min for supine stress and rest images, and 3 min for prone stress and rest images. All supine images were gated. Left ventricular ejection fraction was determined using commercial software (QGS, Cedars-Sinai, Los Angeles, CA). Patients were instructed to abstain from products containing caffeine for 12 h before the test. Beta-blockers and calcium channel antagonists were ceased 24 h before testing and nitrates were withheld for at least 12 h before testing. The study protocol was approved by the institutional ethics committee and written informed consent was obtained from all patients.

Radiopharmaceutical accumulation in the myocardium was evaluated by 2 cardiologists (blinded to clinical data) using a 5-point scale: 0, normal; 1, slight reduction in uptake; 2, moderate reduction in uptake; 3, severe reduction in uptake; and 4, absence of radioactive uptake. The total sum of the scores for all the segments during stress and at rest was designated as the summed stress scores (SSS) and the summed rest scores (SRS), respectively. The SSS minus SRS was defined as the summed difference score (SDS). Perfusion defects in the inferolateral territory (i.e., inferolateral territory that includes segments 4, 5, 10, 11, and 15) were evaluated on a per-patient basis using the 17-segment model approved by the American Society of Nuclear Cardiology [10]. Disagreements in image interpretation were resolved by reaching a consensus after extensive discussion. Abnormalities suggestive of inferolateral ischemia were considered significant if they were present in both the supine and prone images. On the other hand, both images showed normal perfusion images, the images were regarded as no ischemia. When there were disparate findings between the supine and prone scans, we regarded the patients having no CAD.

2.2. Angiographic analysis

All invasive coronary angiograms were viewed by experienced cardiologists who were unaware of the MPI results. None of the patients had myocardial infarction (MI) or revascularization in the interval between coronary angiography and MPI. The presence of obstructive CAD was defined as ≥75% stenosis of the artery.

2.3. Statistical analysis

All continuous variables were expressed as mean ± SD. Two-tailed Student's *t*-test was used for comparisons between continuous variables. Chi-squared or Fisher's exact tests for small sample sizes were used for comparing categorical variables. A p-value of <0.05 was considered significant. The ability of imaging quantification to predict ≥75% stenosis of inferolateral CAD was examined using receiver operating characteristic (ROC) curve analysis.

3. Results

3.1. Patient characteristics

Patient characteristics are shown in Table 1. Of the 322 patients who successfully underwent MPI in the supine and prone positions, 53 (16.5%) and 269 (83.5%) patients had angiograms 17.4 ± 30.0 days before and 4.5 ± 1.2 days after their stress MPI, respectively. Mean age was 68.8 years and 73.3% were men. Mean body mass index was 24.6 kg/m^2. Among the risk factors for CAD, the prevalence of hypertension was the highest at 79.8%. A total of 72 (22.4%) patients had a history of inferolateral MI. Of these, wall motion evaluated by QGS was akinesis in 14 patients (19.4%), severe hypokinesis in 13 patients (18.1%), hypokinesis in 32 patients (44.4%), and normal in 13 patients (18.1%).

3.2. MPI findings

Of the 322 patients who underwent MPI and coronary angiography, perfusion defects in the inferoposterior area was seen in the supine, prone, and combined supine and prone scans in 124 (38.5%), 102 (31.7%), and 61 (18.9%) patients, respectively (Fig. 1).

Table 1
Patient characteristics.

Age (years)	68.8 ± 8.4
Male	236 (73.3%)
Body mass index (kg/m^2)	24.6 ± 3.3
CAD risk factors	
Hypertension	257 (79.8%)
Diabetes	133 (41.3%)
Hyperlipidemia	209 (64.9%)
Smoking	73 (22.7%)
Family history of CAD	37 (11.5%)
Prior MI	131 (40.7%)
Inferolateral	72 (22.4%)
Anteroseptal	61 (18.9%)
Prior PCI	229 (71.1%)
Prior CABG	19 (5.9%)
Myocardial perfusion imaging	
SSS	8.4 ± 6.4
SRS	7.7 ± 6.5
SDS	0.7 ± 2.6
No. of diseased vessels	
3	2 (0.6%)
2	3 (0.9%)
1	97 (30.1%)
0	220 (68.3%)

CABG, coronary artery bypass graft; CAD, coronary artery disease; MI, myocardial infarction; PCI, percutaneous coronary intervention; SDS, summed defect score; SRS, summed rest score; SSS, summed stress score.

3.3. Coronary angiography findings

A total of 102 (31.7%) of 322 patients had obstructive CAD (≥75% stenosis) (Table 1). Although most patients had single vessel disease, 3 patients had 2-vessel disease (left anterior descending coronary artery and left circumflex coronary artery) and 2 patients had 3-vessel disease. The number of stenosed left anterior descending, left circumflex, and right coronary arteries were 41, 34, and 34, respectively.

3.4. Relationship between MPI and angiography findings

The prevalence of CAD was the highest (69%) in patients with abnormal findings on both supine and prone MPI scans; the majority of patients (97%) with normal supine and prone scans did not have CAD. In patients with disparate findings between the supine and prone scans, significant stenosis was observed in 14% and 17% of patients with abnormalities in the supine or prone scan alone, respectively (Fig. 1). The representative case is demonstrated in Fig. 2.

The sensitivity, specificity, and accuracy of MPI supine, prone, and combined supine and prone scans are shown in Fig. 3. The corresponding sensitivity for detecting inferolateral ischemia was 82% (51/62), 79% (49/62), and 68% (42/62) ($p = 0.14$) and the specificity for detecting inferolateral CAD was 72% (187/260), 80% (207/260), and 93% (241/260) ($p < 0.0001$). The accuracy of supine scans and combined supine and prone scans for detecting inferolateral ischemia was 74% and 88%, respectively ($p < 0.0001$).

The area under the curve for detecting inferolateral ischemia was 0.769 (95% confidence interval [CI] 0.705–0.833) for supine scans and 0.793 (95% CI 0.728–0.858) for prone scans, which was increased to 0.802 (95% CI 0.730–0.875) when combined supine and prone imaging was used ($p < 0.05$).

3.5. Relationship between patient characteristics and MPI diagnosis

Univariate analysis demonstrated that the positive rates of history of inferolateral MI were higher in patients with a false diagnosis based on MPI findings than in those with a true diagnosis (43.6% vs. 19.4%, $p = 0.001$; Table 2). Other factors including BMI and sex were similar between the two groups. Logistic regression analysis demonstrated