Evaluation of regional myocardial perfusion in patients with severe left ventricular dysfunction: Comparison of $^{13}$N-ammonia PET and $^{99m}$Tc sestamibi SPECT

Niels Peter Rønnow Sand, MD, Morten Bøttcher, MD, Mette M. Madsen, MD, Torsten T. Nielsen, MD, DMSci, and Michael Rehling, MD, DMSci

Objective. Positron emission tomography (PET) scanning with $^{13}$N-ammonia and $^{18}$FDG is well established for the detection of myocardial viability. Due to the limited availability of PET facilities, recent studies have combined technetium $^{99m}$Tc sestamibi single photon emission computed tomography (SPECT) with $^{18}$FDG PET or $^{18}$FDG SPECT. This approach enables simultaneous assessment of regional myocardial blood flow and metabolism and substantially increases the capacity for viability detection. To validate whether $^{99m}$Tc-Sestamibi SPECT can replace $^{13}$N-ammonia PET, we compared these two modalities in patients with severe left ventricular dysfunction due to coronary artery disease.

Materials and Methods. Thirty-one patients (mean age 57 ± 8 years; mean ejection fraction 27% ± 8%) with angiographically verified coronary artery disease were included. In random order, ammonia-PET and sestamibi-SPECT scans were performed. In a 20-segment model of the left ventricle, two blinded observers scored a total of 610 segments on a five-point scale. In a subset of 20 patients, 400 segments were scored twice to evaluate the observer variations of the two techniques. Segmental score differences were used to compare the imaging modalities. The impact on viability detection was assessed by combining the two flow tracers with FDG PET.

Results. Segmental comparison of the PET and SPECT studies yielded similar (difference ≤1) results in 74% of segments, reflecting regional concordance values in the lateral, apical, anterior, septal, and inferior myocardial walls of 86%, 82%, 71%, 66%, and 63%, respectively. The differences in the septal and inferior walls were primarily due to overestimation of perfusion defects by sestamibi SPECT, which yielded a higher proportion of mismatch patterns in those regions. The overall observer variations of the PET and SPECT studies were 7.5% and 5.8%.

Conclusion. Myocardial perfusion imaging with $^{13}$N-ammonia PET and $^{99m}$Tc-sestamibi SPECT yielded similar results in patients with severe left ventricular dysfunction, except for the septal and inferior regions. In these regions, SPECT tended to overestimate perfusion defects. Hence, attenuation correction should be considered when combining FDG PET and sestamibi SPECT for diagnosing myocardial viability to avoid overestimation of mismatch patterns in those regions. (J Nucl Cardiol 1998;5:4-13.)

Key Words: myocardial perfusion • left ventricular dysfunction • $^{13}$N-ammonia PET • $^{99m}$Tc-sestamibi SPECT

During the last decade, several studies have demonstrated that positron emission tomography (PET) is able to distinguish between scar and viable myocardium in regions with left ventricular dysfunction. Hence, the technique is able to predict the potential for improving contractility after revascularization. This distinction is important, particularly in patients with severe contractile dysfunction of the left ventricle. Patients with viable regions benefit from revascularization, while patients without signs of myocardial viability are at increased risk...
of perioperative complications and accordingly should be treated medically or considered for heart transplantation.

The evaluation of viability by PET is most commonly performed with a combination of a flow study, $^{15}$N-ammonia or $^{15}$O-water, and a metabolic study, $^{18}$fluorodeoxyglucose ($^{18}$FDG). However, in recent studies it has been shown that evaluation of regional myocardial uptake of $^{18}$FDG by SPECT provides similar clinical information as $^{18}$FDG PET despite the inherent differences in resolution of the two methods. Due to these promising results, recent studies have combined $^{18}$FDG and $^{99m}$Tc-sestamibi either by means of a dual-isotope SPECT protocol that allows simultaneous assessment of perfusion and metabolism or a combination of a sestamibi-SPECT and FDG PET study. Due to the relatively high costs and limited availability of PET facilities, both approaches would substantially increase the capacity for viability detection.

Recent studies of the PET technique showed no difference in regional myocardial uptake of $^{13}$N-ammonia and the positron-emitting substance $^{99m}$Tc-sestamibi. In one of these studies performed in patients with anterior perfusion defects, the severity within the perfusion defect evaluated by $^{99m}$Tc-sestamibi PET and $^{13}$N-ammonia-PET was compared to the results of $^{99m}$Tc-sestamibi SPECT scans in the same patients; it was found that sestamibi SPECT overestimated perfusion defects compared to both PET modalities. Whether these discrepancies are of similar magnitude in patients with severe left ventricular dysfunction due to coronary artery disease who are candidates for evaluation of myocardial viability has not been evaluated. Consequently, the purpose of this study was to compare regional myocardial perfusion imaging with $^{13}$N-ammonia PET and $^{99m}$Tc-sestamibi SPECT during resting conditions in patients with severe left ventricular dysfunction due to coronary artery disease.

**METHODS**

**Patient Population**

The study population consisted of 36 patients with angiographically verified single-, double-, or triple-vessel coronary artery disease and severely decreased left ventricular ejection fraction (27% ± 8%) who were consecutively referred for PET scan evaluation of myocardial viability. Patients were subjected to the PET and SPECT studies in random order. The delay between studies had a median of 14 days (range 1 to 54 days). No clinical events or major changes in medication occurred between the studies. Informed consent was obtained, and the study was approved by the local ethical committee and carried out in accordance with the Helsinki II declaration.

**PET Imaging**

A Siemens/CTI 961 positron tomograph, which simultaneously acquires 47 transaxial images, was used for image acquisition. This scanner has an axial field of view of 15 cm, an intrinsic in-plane spatial resolution of 5.5 mm full-width half-maximum (FWHM), and an interplane spacing of 3 mm. The transaxial images were reconstructed with a Shepp filter with a cut-off frequency of 0.3 Nyquist, resulting in an effective in-plane resolution of 7 mm FWHM.

After a 15-minute transmission scan to correct for photon attenuation, a 20 ml bolus of N-13 ammonia (20 mCi/740 MBq) was injected over a 30 second period in a cubital vein. A dynamic imaging sequence was started simultaneously.

The dynamic imaging protocol consisted of twelve 10-second, two 30-second, one 60-second, and one 15-minute image (static image). Only the static image was used for image interpretation.

The FDG scan was acquired after injection of 370 MBq $^{18}$FDG. Patients were given 100 ml 50% glucose 30 minutes before FDG injection. Twenty-five minutes were allowed for accumulation of FDG. Three consecutive 10-minute frames were acquired, and the last frame was used for diagnosis.

PET images were stored as $1.44 \times 1.44 \times 3.125$ mm$^3$ voxels in a $128 \times 128 \times 47$ matrix. These images were resized to $5.76 \times 5.76 \times 5.76$ mm$^3$ cubic voxels and centered in $64 \times 64 \times 21$ matrices with linear interpolation. Furthermore, the original format of the PET files were converted from ECAT to PEGASYS to prepare it for final evaluation in a software program identical to that used to analyze the SPECT data (ADAC).

**SPECT Imaging**

$^{99m}$Technetium sestamibi (Cardiolite) was prepared with a sterile, nonpyrogenic, lyophilized kit. Bolus injections of 700 MBq ± 10% were performed in an antecubital vein, followed by 10 ml saline. A glass of milk was given 45 minutes after tracer injection. Imaging was performed 1 hour after injection. SPECT acquisition was performed with patients in the supine position with a single-headed rotating gamma camera (Geneysys, ADAC) and a high-resolution, parallel-holed collimator. Fifty-four projections of 20 seconds each were obtained over a noncircular 180-degree arc, extending from the 45-degree right anterior oblique to the 45-degree left posterior oblique position. A 20% symmetric energy window centered on the 140 KeV peak was used. All projection images were stored on magneto-optic disks in a $64 \times 64$ matrix.

Filtered backprojection was performed with a Butterworth filter with a cut-off frequency of 0.35 cycles/pixel, order 5, to reconstruct transverse axial tomograms. No attenuation or scatter correction was used. Raw data were checked for patient motion. Slices were reoriented after reconstruction according to the anatomic axis of the heart. Slices were displayed as short-axis, vertical, and horizontal long-axis slices.