Assessment of myocardial perfusion and viability with technetium-99m methoxyisobutylisonitrile and thallium-201 rest redistribution in chronic coronary artery disease


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Abstract. We compare thallium-201 rest redistribution and fluorine-18 fluorodeoxyglucose ([18F]FDG) for the assessment of myocardial viability within technetium-99m methoxyisobutylisonitrile (MIBI) perfusion defects in 27 patients with chronic stable coronary artery disease. The following studies were performed: (1) stress 99mTc-MIBI, (2) rest 99mTc-MIBI, (3) 201Tl rest-redistribution single-photon emission tomography, (4) [18F]FDG positron emission tomography. The left ventricle was divided into 11 segments on matched tomographic images. The segment with the highest activity at stress was taken as the reference (activity=100%). Perfusion defects at 99mTc-MIBI rest were classified as severe (activity<50%), moderate (activity 50%-60%) or mild (activity 60%-85%). Uptakes of [18F]FDG and rest-redistributed 201Tl were recognized as significant if they exceeded 50% of that in the reference segment. Among the 33 segments with severe 99mTc-MIBI rest perfusion defects, 21 had significant [18F]FDG and 10 significant rest-redistributed 201Tl uptake. As regards the 37 segments with moderate defects, [18F]FDG was present in 29 and 201Tl in 31, while of the 134 segments with mild defects, 128 showed [18F]FDG uptake, and 131, 201Tl uptake. In conclusion, there is an inverse relationship between the severity of 99mTc-MIBI perfusion defects and the uptake of rest-redistributed 201Tl and [18F]FDG. Both tracers are adequate markers of viability in mild and moderate defects; in severe defects 201Tl might underestimate the presence of viability as assessed by [18F]FDG.

Key words: Single-photon emission tomography – Positron emission tomography – Myocardial perfusion – Myocardial viability

Introduction

Assessment of myocardial perfusion and viability is important for the diagnosis, staging and management of patients with coronary artery disease (CAD). The cost and efficacy of therapeutic options require careful selection of patients who may benefit from the available pharmacological and/or interventional treatments.

Myocardial perfusion, under stress and rest conditions, has for years been routinely assessed by scintigraphy with thallium-201. However, this cationic indicator is now being progressively replaced by radiotracers labelled with technetium-99m such as 99mTc-methoxyisobutylisonitrile (99mTc-MIBI) [1-7]. This tracer offers similar diagnostic accuracy and better image quality than 201Tl when used for perfusion studies with planar techniques or single-photon emission tomography (SPET) [8-10].

The identification of perfusion defects, under rest conditions, raises the question of whether unperfused areas are necrotic or viable and can thus benefit from coronary artery bypass graft (CABG) or percutaneous transluminal coronary angioplasty (PTCA). It has recently been estimated that the assessment of viability is important in 10%-20% of patients with an established diagnosis of CAD in order to rescue hibernating myocardium [11]. Several strategies have been proposed to identify viable myocardium within resting perfusion defects. Extensively used methods take advantage of the kinetic properties of 201Tl with different protocols; these include imaging of 201Tl distribution 4–24 h after i.v. administration of the radiotracer at rest, or imaging of the distribution of 201Tl following its re-injection immediately after the standard 201Tl stress-4 h redistribution study [12-17]. The results obtained with such protocols have also been related to those obtained by positron emission tomography (PET) with fluorine-18 fluorodeoxyglucose.

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([18F]FDG), which is considered to be the reference method for identifying hibernating myocardium [18-22].

Recent studies have established the adequacy of 201TI rest redistribution and [18F]FDG in identifying myocardial viability within perfusion defects assessed with 99mTc-MIBI [23-25]. These studies were carried out in different laboratories and in patients not homogeneous for degree of CAD, presence of myocardial infarction and left ventricular function.

The aim of the present investigation was to directly compare 201TI rest redistribution and [18F]FDG for the assessment of myocardial viability within 99mTc-MIBI perfusion defects in patients with chronic stable CAD and regional dysfunction of the left ventricular wall.

Materials and methods

Patients

We studied 27 patients (25 men) with chronic stable CAD and regional dysfunction of the left ventricular wall, ranging in age from 23 to 75 years (mean 55 years). All patients satisfied the following inclusion criteria: (a) reduction>50% in the luminal diameter of at least one major epicardial coronary artery with coronary anatomy suitable for revascularization as determined by coronary angiography; (b) non-recent (>4 weeks) Q-wave myocardial infarction as proven by electrocardiographic and serum enzyme criteria; (c) regional wall motion abnormalities at rest associated with moderate depression of left ventricular function (ejection fraction=43%±6%) as documented by left ventriculography and twodimensional echocardiography; (d) absence of diabetes mellitus and left ventricular hypertrophy. Coronary angiography, performed<4 weeks before the scintigraphic studies, showed one- vessel disease in 15 patients, two-vessel disease in nine and three-vessel disease in three. All cardiac medications were withdrawn 48 h before each scintigraphic study, except for sublingual nitroglycerin if it was required for chest pain. Informed consent was obtained from all patients and the protocol was approved by the H San Raffaele Ethics Committee.

Scintigraphic studies

99mTc-MIBI stress studies. The patients underwent treadmill testing using the modified Bruce protocol with continuous monitoring of three ECG leads and 12-lead ECG during each minute of exercise. Exercise end-points were one of: severe angina,>2 mm ST segment displacements, hypotension, frequent ventricular premature beats or sustained tachyarrhythmias, physical exhaustion and severe dyspnoea. In 80% of the patients, heart rate increased to more than 85% of the maximal predicted rate. Upon approaching the end-points of the exercise, 20 mCi of 99mTc-MIBI was injected intravenously and the exercise was continued for at least 1 min. Image acquisition was started 2 h later with a rotating gamma camera (Orbiter 7000, Siemens, Erlangen) equipped with a low-energy high-resolution parallel-hole collimator. Energy discrimination was achieved by a 15% window centered over the 140-KeV photopeak of 99mTc. The camera was rotated in 6° increments, collecting 64 views over 360° for 30 s each. Each acquisition was reconstructed by filtered back-projection using a Butterworth filter with a cut-off frequency of 0.4 cycles/pixel and a power factor of 5. No attenuation correction was performed. Spatial resolution in the transaxial plane was 1.8 cm.

99mTc-MIBI rest studies. Two days after the stress 99mTc-MIBI study, patients underwent a rest study following the intravenous injection of 25 mCi of 99mTc-MIBI at rest, using the acquisition protocol described above.

201TI rest-redistribution studies. Within 2 weeks of 99mTc-MIBI SPET, rest-redistribution 201TI SPET studies were performed. Myocardial tracer distribution was assessed 4 h after injection of 2 mCi of 201TI under steady state resting conditions. 201TI images were obtained using the same rotating gamma camera described above, equipped with a low-energy all-purpose parallel-hole collimator centered on the 72-KeV photo peak of 201TI with a 20% window. Thirty-two views were collected for 35 s each by rotation of the camera through a 180° arc starting from the 45° right anterior oblique view. Each study was reconstructed by filtered back-projection using a Butterworth filter, a cut-off frequency of 0.35 cycles/pixel and a power factor of 5.

[18F]FDG studies. Within 2 weeks of 99mTc-MIBI scintigraphic study, all patients underwent metabolic PET studies following an oral glucose load (50 g dissolved in water) to measure exogenous [18F]FDG utilization. PET studies were performed with a fourring whole-body positron emission tomograph (Model ECAT 931/04-12; Siemens/CPS, Knoxville, Tenn., USA) which allows simultaneous data collection from seven equally spaced transaxial planes (four direct and three cross planes; slice thickness 6.75 mm), covering an axial field of view of 5.4 cm.

Before tracer injection, two consecutive 10-min transmission scans were performed with a germanium-68/gallium-68 source external to the patient. Following the transmission scan, each subject received an i.v. pulse of approximately 250 MBq of [18F]FDG. To allow sufficient time for myocardial [18F]FDG uptake, emission scan was carried out between 40 and 60 min after tracer injection. Two consecutive 10-min emission scans were performed and 14 contiguous transaxial slices were reconstructed (128×128 matrix, zoom 3, pixel size=1.565 mm, 6.75 mm thick) using the Hann filter with a cut-off frequency of 0.5 cycles/pixel. Data were corrected for 18F decay and for attenuation of emitted 511-KeV annihilation photons by the tissue with the coefficients measured by the transmission scan. Under these conditions, the spatial resolution was 8 mm full-width at half maximum.

Data analysis

Transverse tomographic images of the different studies were transferred to a Sun Sparc work station connected via Ethernet to the SPET and PET computers. Images were then reoriented on short and vertical long axes. Short-axis slice thickness was normalized to 1 cm and pixel size to 3.12 mm in all studies. The re-alignment of short and vertical long-axis images obtained during the different studies for each patient was carried out by three independent observers by considering as reference the insertion of the right ventricle and the papillary muscles on PET studies; disagreements were resolved by consensus. For each study, the vertical long-axis image that best defined the apex and six short-axis tomographic images were considered: three for the basal left ventricle and three for the mid-left ventricle.

To semiquantitatively compare activity of the different studies, 11 myocardial segments (five basal, five mid-ventricular and the...