Direct Comparison of Fluorine-18-FDG SPECT, Fluorine-18-FDG PET and Rest Thallium-201 SPECT for Detection of Myocardial Viability

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Twenty consecutive patients were evaluated for presumptive myocardial viability using rest Tl-SPECT, FDG-PET and FDG-SPECT. The FDG studies were performed after rest Tl-SPECT to guide intervention or medical management. **Methods:** Twenty patients with proven coronary artery disease, either known or suspected to have previous myocardial infarction and persistent perfusion defects shown by rest reinjection Tl-SPECT, underwent FDG-PET and subsequent FDG-SPECT with a three-detector SPECT camera. FDG-PET and SPECT images were compared by five observers to determine if any fixed thallium segments were visualized by either FDG imaging method. **Results:** Thirteen of 60 fixed segments were shown probably viable by FDG-SPECT (8 of 20 patients) and 14 of 60 by FDG PET (7 of 20 patients). Two patients had fixed thallium segments found probably viable with FDG by SPECT alone and one by PET alone. **Conclusion:** FDG is shown to provide additional information about myocardial viability. Both SPECT, using a three-detector camera, and PET with a specialized instrument are equally effective for imaging FDG in this application.

Key Words: fluorodeoxyglucose; SPECT; PET; myocardial viability; thallium

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PET imaging with ^{18}F-fluorodeoxyglucose (FDG) is an established but not generally available method for detecting myocardial viability. Injection of [^{201}Tl]thallous chloride (thallium) during rest with subsequent SPECT imaging has been thought to be an effective alternative to FDG imaging when FDG imaging is not available (*1,2*).

Several protocols have been described that use different doses of thallium and times of injection and imaging. It appears that a thallium study on a different day than the stress procedure, readministering the thallium at rest, and waiting one to three hours for redistribution before imaging provides an inconvenient but accurate assessment of myocardial viability (*1–3*).

There are relatively few PET instruments available for clinical use but multidetector SPECT cameras are common and supplied by several manufacturers. We directly and prospectively compared FDG images obtained on a PET instrument and those obtained shortly afterwards with a SPECT three-detector camera. Additional FDG was not given to the patients and the FDG images were also compared to rest thallium-SPECT images. The intent was to find if additional cardiac segments were identified as likely viable with FDG when compared to rest thallium images and if FDG imaging could be successful without using a PET tomograph. This study was performed on patients who were undergoing FDG imaging for myocardial viability for clinical indications and were not specifically studied for an investigation.

Our practice is to obtain rest thallium images for initial viability estimates. Only patients with signifant segments not visualized with rest thallium images are referred for FDG studies. Virtually all patients, except those referred from outside centers, also had abnormal stress-to-redistribution thallium imaging unless stress testing was contraindicated. The results of the stress-to-redistribution examinations are not reported here.

METHODS

We examined the images in 20 consecutive patients studied with FDG for estimates of viability of cardiac segments. This was done for clinical reasons to plan appropriate interventions or recommend medical therapy. All had symptoms or history compatible with coronary artery disease. All patients had significant fixed defects on reinjection rest thallium images.

Rest thallium imaging was performed as follows: patients were instructed to either fast or eat only a light breakfast (toast, cereal with skim milk) the day of the examination. About 111 MBq to 148 MBq (3 to 4 mCi) of ^{201}Tl as thallous chloride was administered intravenously. The patients remained at rest or only did light activity for 3 hr and then the SPECT acquisition was done.

FDG-PET was performed after obtaining a transmission scan for attenuation correction and ^{13}N-ammonia perfusion imaging. Noninsulin requiring patients were fasted, given a glucose load,

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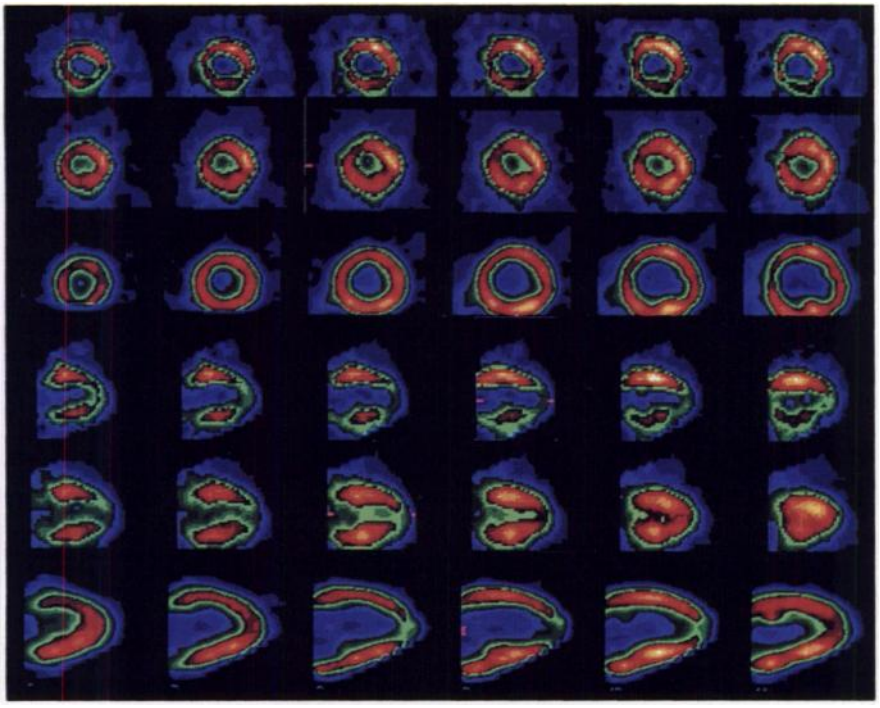

FIGURE 1. Rest thallium (1st and 4th rows), FDG-SPECT (2nd and 5th rows) and FDG-PET (3rd and 6th rows) short axis and vertical long axis images in a patient with a fixed apical thallium defect and inferior wall abnormalities. FDG-SPECT and FDG-PET show some increased uptake in these areas but with essentially little uptake in the apex. There is near equality between the FDG-PET and FDG-SPECT images.

and had serial glucose level measurements prior to administration of about 370 MBq (10 mCi) of ^{18}F-FDG at 1 hr. Glucose levels were controlled by intravenous insulin as required to lower blood glucose to or below 150 mg/dl. Diabetics requiring insulin followed their usual schedule and additional insulin was administered as needed to control serum glucose levels.

After allowing 30 min for incorporation, tomographic images of the myocardium were acquired with a Siemens Model 931 tomograph (Siemens, Hoffman Estates, IL) with in-plane resolution of about 8 mm and slice thickness of about 3.5 mm. Data were acquired from 30 to 50 min after injection. Thirty-one transverse slices were reconstructed using a Hanning filter with a 0.35 cutoff. They were displayed as the mean of four adjacent section slices in short-axis, horizontal long-axis and vertical long-axis orientation. This produced sections effectively about 14 mm thick which were comparable to the SPECT images. A color scale that displays the count range from 50% to 100% of maximum as reds and yellows, from 30% to 50% as green and below 30% as blue was used for all images (Figs. 1 and 2).

After completion of PET imaging, patients were imaged using the SPECT camera. The PET and SPECT instruments are in different hospitals about a half mile apart. Patients had to be transported, and SPECT imaging did not typically begin until at least 1 hr after completion of the PET study and frequently about

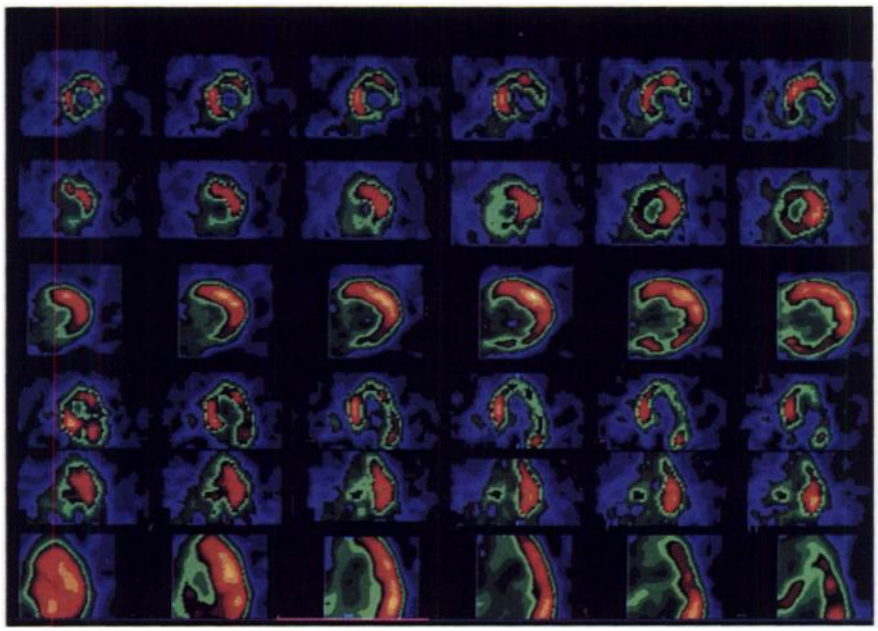

FIGURE 2. Rest thallium (1st and 4th rows) demonstrates distal lateral and inferior wall fixed defects. FDG-SPECT (2nd and 5th rows) and FDG-PET (3rd and 6th rows) demonstrates hypermetabolism in these segments. Because of the marked increase in FDG uptake the septum appears suppressed. This is a mismatch indicating a severe decrease in perfusion but retained glucose metabolism in the lateral and inferior walls.

2 hr after the PET study. SPECT imaging was also done to ensure that the heart would be completely visualized as the field of view since PET tomograph is narrow and portions of large hearts may not be seen.

A Trionix 88 (Trionix, Twinsburg, OH) three-detector gamma camera equipped with high-energy collimators was used. Acquisition parameters were matrix 64 × 128 pixels, 35 sec per stop, 4° steps, 30 stops; reconstruction parameters were Butterworth filter (0.702 Nyquist, 0.50 cutoff, rolloff 4.00), 32 × 32 pixel area reconstructed around the heart, and 1.6 magnification display as is used routinely for rest thallium SPECT. For patients in whom it took a long time to acquire SPECT scans; images were reconstructed using a 0.40 cutoff. A four-point elliptical attenuation correction was applied with an attenuation coefficient of 0.089 as compared to 0.120 for thallium imaging. Typical count rates for FDG imaging were similar or higher in some cases to those of rest thallium studies in the same patient.

Low-energy, ultrahigh resolution and parallel-hole (LEUR-PAR) collimators were used for thallium imaging. The resolution specified by the FWHM of the line response function was 10 mm at 100 mm from the collimator face with no scattering material. The high-energy collimators used for ^{18}F imaging have hexagonal holes arranged in a honeycomb lattice. The hole length is 78.2 mm and the septal thickness is 1.74 mm. The estimated septal penetration for 511 keV photons is 8.6%. Sensitivity measurements using NEMA recommendations ranged from 3.56 kcps/mCi to 3.65 kcps/mCi. Resolution was estimated from line source measurements and was 13.1 mm FWHM at 100 mm without scattering material.

All but three rest thallium images were obtained from the same SPECT multidetector camera with the above parameters. Three patients were imaged using a General Electric 400AT upgraded with a new crystal and detector electronics and then fitted with a collimator designed for thallium imaging. Acquisition was 180°, LPO to LAO, 32 stops, 30 sec per stop, 64 × 64 pixel matrix reconstructed using the Siemens ICON system, a Butterworth filter with a cutoff of 0.4, order 5 and a final display of a 32 × 32 section of the 64 × 64 matrix.

FDG-PET images were displayed in transparent color as a single patient study. Rest thallium and FDG-SPECT images were displayed as adjoining comparable sections either as a transparency when thallium imaging was done with the single-detector camera or on dye-sublimated color prints when done on the three detector camera. Five independent observers were given the 20 image sets and were instructed to examine them as image pairs: PET-FDG versus rest thallium, FDG-SPECT versus rest thallium. They were then asked to compare PET-FDG and FDG-SPECT image sets and specify which they subjectively preferred to interpret for clinical purposes. Disagreements were resolved by consensus.

Each image set was divided into seven perfusion areas: anterior, septum, apex, inferior, distal lateral, proximal lateral and posterior basal segments. These correspond to the usual coronary artery distributions.

Fixed rest thallium defects were defined as myocardial segments with less than 50% uptake when compared with the maximum uptake in the remainder of the myocardium. Observers rated these segments with rest defects but visualized with FDG on a three-point scale:

1=little FDG additional uptake, visible, but probably not significant.

2=clear FDG uptake thought significant and above 50% of maximum FDG uptake in the myocardium.

3=FDG uptake essentially filling the segment (the segment shows no discernable defect).

Those rated as having FDG uptake of two or three were considered as clinical evidence that that segment was probably viable when compared to the fixed thallium defect.

RESULTS

The 20 patients had a total of the 60 segments with thallium uptake less than 50% of the maximum uptake. Eight of the 20 patients studied with FDG-SPECT had at least one segment identified as viable with FDG and not with rest ^{201}Tl. Fourteen additional segments in total were found viable that would have been thought nonviable if rest ^{201}Tl alone was used as a standard. In two of these patients, viability was not identified by FDG-PET.

Seven of 20 patients studied with FDG-PET had at least one segment identified with FDG and not with thallium and in total 13 additional segments were seen with FDG alone. One of these patient's viability was not identified with FDG-SPECT.

One of the two patients seen only with FDG-SPECT had a segment score of two, while the same segment was rated one with FDG-PET and the other had a relatively small area in the apex. A total of nine patients had viable segments found with one or the other technique. FDG-SPECT found 14 additional segments and FDG-PET found 13 out of 60 segments thought fixed with rest thallium.

Fourteen of the 20 FDG-PET and FDG-SPECT images were considered clinically equivalent, three PET images judged superior and three FDG-SPECT images superior. A summary of the results are provided in Table 1.

DISCUSSION

Although both clinically applied viability techniques (^{18}F-FDG and rest thallium) have been well documented as effective, we are aware of only a few direct comparisons (*4,5*). Tamaki et al. (*6*) reported such a comparison; however, thallium was given immediately after the redistribution images in low dose and rest imaging was started 10 min later. With this technique 25% of fixed thallium segments were shown viable by PET and FDG. The FDG-PET studies apparently did not follow glucose loading. Dilsizian et al. (*7*) found that 17% of segments with severely reduced thallium uptake were found likely viable with FDG. Our

TABLE 1
Comparison of FDG-PET and FDG-SPECT Uptake in Segments with Fixed ^{201}Tl Defects

	SPECT +	SPECT −
PET +	11	3
PET −	2	45

+ is glucose uptake and − is no glucose uptake.

results are consistent with these reports. Altehoefer et al. (*8*) showed a lower discordance between rest (74 MBq thallium, 30 min delay) and glucose loaded PET-FDG (50 g of glucose 1 hr before injection of 200–300 MBq of FDG). Only 14% of thallium defects (mostly in the posterior territory) had increased FDG uptake. Altehoefer et al. also pointed out the high cost and lack of general availability of FDG-PET.

The use of positron-labeled pharmaceuticals with gamma camera imaging is certainly not new even with tomography (*9*). There are, however, few reports of using these agents with modern multidetector SPECT instruments (*10–12*).

We had previously thought that rest thallium imaging using 111 MBq to 148 MBq (3 mCi to 4 mCi) doses with a 3-hr delay before imaging would likely be equivalent to ^{18}F-FDG imaging for viability evaluation; however, this seems not to be the case. Nine of the 20 patients studied had at least one segment found viable with either FDG-PET or FDG-SPECT. It is possible that the slightly different results between the two FDG image sets may have been the result of the delay between the PET and SPECT acquisitions. There is, however, no literature to support this.

We believe that the detection of additional visualized segments reported here is further evidence that FDG is superior in detecting severely ischemic myocardial segments compared to a very conservative rest thallium imaging protocol.

FDG cannot be used for clinical decision making without an independent myocardial perfusion marker. Severely ischemic cardiac segments will accumulate FDG avidly and obscure visualization of normally perfused or segments with only minimal reduction of blood flow. Rest thallium imaging now seems an appropriate perfusion marker to define which segments are either severely ischemic or infarcted and that should be evaluated with FDG to guide management.

FDG images, when displayed as either single-pixel slices or four-slice mean images, obtained with the PET tomograph are aesthetically superior to the FDG-SPECT images. They have sharper myocardial wall margins and more accurate depiction of wall thickness than FDG-SPECT images. However, there seems to be little clinically relevant difference in detection of segments with FDG uptake between the instruments. Since the FDG-SPECT images were always acquired later than the FDG-PET studies, these images should have been at a significant disadvantage. We now have no hesitation to study patients for clinical indications with the SPECT camera as the primary instrument when necessary with the appropriate FDG cardiac protocols.

CONCLUSION

Our data show that FDG imaging with PET or SPECT reveals a significantly higher number of myocardial segments with probable viability than rest thallium imaging. Secondly, FDG myocardial imaging can be successfully implemented in any laboratory equipped with a multidetector SPECT camera with suitable high-energy collimation. This opens the use of this powerful technique to many more patients who would benefit in locations where PET equipment is not available.

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