Impact of photon energy recovery on the assessment of left ventricular volume using myocardial perfusion SPECT

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Background. **Photon energy recovery (PER) is a spectral deconvolution technique validated for scatter removal in patients and phantom studies. The purpose of this study was to examine the impact of PER on left ventricular volume measurement based on myocardial perfusion single photon emission computed tomography (SPECT).**

Methods and Results. **SPECT acquisitions were performed by use of a static cardiac phantom and in 25 patients after a rest injection of technetium 99m sestamibi by use of multiple energy windows (126-136, 137-144, and 145-154 keV). Data were successively reconstructed with and without PER, by use of iterative reconstruction and post-processing filtering (Butterworth filter; order, 5; cutoff, 0.30 cycles/pixel). Image contrast was evaluated in reconstructed data, and volumes were calculated by use of QGS. PER increased reconstructed image contrast from 62% ± 2.7% to 84.3% ± 5.7% in the phantom studies ($P < .0001$) and from 49% ± 2% to 73% ± 2% in patients ($P < .0001$). Although it remained underestimated ($P < .0001$), phantom volume was higher after PER correction compared with uncorrected data (50.9 ± 0.8 mL vs 44.6 ± 1 mL, $P < .0001$). The error in volume measurement was decreased by PER correction (16.6% ± 1.3% vs 27% ± 1.7% [uncorrected data], $P < .0001$). In patients, left ventricular volume increased from 83 ± 10 mL to 91 ± 10 mL ($P < .0001$), and the PER-induced volume increase was correlated with the image contrast increase ($r = 0.61$, $P = .001$). Finally, the percentage of volume increase was higher in patients with small left ventricular volumes.**

Conclusions. **PER has a significant impact on image contrast and left ventricular volume measurement by use of perfusion SPECT. PER improves the accuracy of phantom volume assessment. In patients, volume increase is correlated to image contrast increase and is higher in those with small ventricles. (J Nucl Cardiol 2004;11:312-7.)**

Key Words: Single photon emission computed tomography • left ventricular function • scatter correction

Left ventricular (LV) volumes and ejection fraction (EF) can be assessed by use of myocardial perfusion gated single photon emission computed tomography (SPECT).[1-3] As gated SPECT is associated with a considerable increase in noise with a decrease in signal as a result of temporal segmentation, noise suppression and signal recovery comprise a primary goal in gated SPECT reconstruction. With filtered backprojection, image quality is greatly affected by the choice of the filter and its cutoff frequency.[4] In clinical routine, myocardial SPECT images are often heavily filtered by use of low-pass filters and low cutoff frequencies to reduce image noise, leading to an increased spatial blur effect. We previously reported that decreasing the critical frequency of a Butterworth filter alters edge detection, because edges have high frequencies.[5] This spatial blur effect may lead to underestimation of LV volume measurement by use of gated SPECT. Another factor that degrades both visual image analysis and quantitative accuracy is the detection of scattered photons.[6] We recently suggested that reconstruction methods that partially compensate for scatter consequences increase the accuracy of LV volume measurement.[7]

Many methods have been proposed or are still under investigation to cope with scattered photons.[6] Photon energy recovery (PER) is a fully automated method based on a spectral deconvolution analysis and uses iterative recurrent linear regressions, leading to an improvement in the effective resolution of gamma cameras.[8] In practice, it only

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requires splitting the photopeak energy window into several subwindows and does not require list mode acquisitions. PER allows the selection of photons according to their true energy and then separates the unscattered photons from the scattered photons. The technique has been validated in phantom and patient studies for scatter removal and cross-talk correction in simultaneous technetium 99m/thallium 201 imaging.[9-12] The aim of this study was to evaluate the impact of PER on the evaluation of LV volume measurement by use of perfusion SPECT.

METHODS

Phantom Acquisitions

The myocardium was simulated by use of an anthropomorphic torso phantom with a cardiac insert (Data Spectrum Corp, Hillsborough, NC). In the torso phantom, lungs were in place and a posterior solid Teflon column simulated the spine. The cardiac insert consisted of two chambers. The exact volume of the inner chamber, representing the myocardial blood pool, was 61 mL, including the volume of plastic in the inner wall of the heart phantom. No myocardial wall defect was added. The myocardial wall was filled with a saline solution of Tc-99m (37 MBq), and the cardiac blood pool was simulated with a solution of 10% of this volumic activity. The cardiac phantom was then secured in the torso, and a series of acquisitions were performed.

Data Acquisition

Acquisitions were performed with a 90° dual-head gamma camera (DST-XL; SMVi, Buc, France) equipped with low-energy, high-resolution, parallel-hole collimators. The following parameters were the same for all acquisitions: 32 projections over a 180° orbit starting at 315° (clockwise step and shoot), with an acquisition zoom of 1.33 and a 64×64 matrix (pixel size, 6.77×6.77 mm). The bed was positioned at the same height and the scan diameter was similar for all acquisitions. Four consecutive acquisitions were performed with increasing time per projection (10 seconds, 20 seconds, 30 seconds, and 40 seconds). All acquisitions were performed with the multiple energy window facilities available on DST-XL gamma cameras. As previously described,[11] three Tc-99m spectral windows were used for single Tc-99m SPECT acquisition (126-136, 137-144, and 145-154 keV).

Patient Group

Twenty-five consecutive patients without a history of myocardial infarction referred to the Department of Nuclear Medicine (Centre Henri Becquerel, Rouen, France) for a routine evaluation of myocardial perfusion were evaluated 30 minutes after a rest injection of 925 MBq Tc-99m sestamibi. Acquisitions were performed by use of the same parameters that were used for the phantom study, except that the time per projection was set to 30 seconds. SPECT acquisitions were not gated to the electrocardiogram, because the combination of gated SPECT and PER acquisition has not yet been provided by any manufacturer.

Data Processing

All data were processed on a PowerVision workstation (GEMS, Buc, France). The PER method was applied as previously described.[11] Single SPECT data were processed to obtain the following projection data sets:

- Single uncorrected Tc-99m data set, corresponding to the conventional Tc-99m projection data set (ie, the sum of projections recorded in the following windows: 126-136, 137-144, and 145-154 keV)
- Single PER Tc-99m data set, consisting of the conventional Tc-99m projections corrected for scatter

All projection data sets were reconstructed and reoriented into three orthogonal views by use of an automated algorithm (MyoSPECT, Vision 5.0.2; SMVi, Buc, France). All SPECT images were reconstructed by use of iterative reconstruction with an ordered-subset Expectation Maximization algorithm with 16 equivalent iterations (2 subsets and 8 iterations). Additional filtering was then applied (Butterworth filter; order, 5; cutoff frequency, 0.30 cycles/pixel). No attenuation correction was performed.

In the phantom study, image contrast was measured in one reconstructed midventricular small-axis slice by use of the count ratio as follows: $(C_{myoc} - C_{cav})/(C_{myoc} + C_{cav})$, in which C_{myoc} was the mean count statistic in a 2×2–pixel region of interest (ROI) traced within the myocardium and C_{cav} was the mean count statistic in a 2×2–pixel ROI in the LV chamber. In patients, image contrast was measured in one reconstructed midventricular small-axis slice by use of the same formula, but C_{myoc} was calculated as the mean value of the count statistic calculated in 2×2–pixel ROIs placed over the septum, anterior, lateral, and inferior walls.

For each reconstruction, LV volumes were calculated by use of QGS software (Cedars-Sinai Medical Center, Los Angeles, Calif). For phantom acquisitions, the error in volume measurement was assessed by the following ratio: (True volume − Measured volume)/True volume. In patients, the percentage of LV volume (LVV) increase was calculated as follows: (Corrected LVV − Uncorrected LVV)/Uncorrected LVV.

Statistical Analysis

Data are expressed as mean $\pm$ 1 SD. Calculated phantom volumes were compared with theoretical volume (ie, 61 mL) by use of the paired *t* test. The influence of scatter correction by use of the PER method on phantom volume measurement was studied by analysis of variance. The difference between LV volumes evaluated from uncorrected and corrected data was evaluated by use of the paired *t* test. A P value $\leq .05$ was considered statistically significant.

RESULTS

Phantom Data

With regard to phantom data, the PER algorithm significantly increased reconstructed image contrast from