Performance of a New Iterative Reconstruction Algorithm for Cardiac Short-Time Single Photon Emission Computed Tomography: Preliminary Results in an Anthropomorphic Cardiac Phantom Study

O Zoccarato[1], R Campini[1], C Marcassa[2], P Calza[1]

[1]Nuclear Medicine Dept, Salvatore Maugeri Foundation Scientific Institute of Veruno, Veruno (NO), Italy

[2]Cardiology Dept, Salvatore Maugeri Foundation Scientific Institute of Veruno, Veruno (NO), Italy

Abstract

A new iterative reconstruction algorithms (WBR) has been recently proposed for cardiac SPECT. The WBR technology is based on an iterative technique, includes physical parameters such as LSF modelling, collimator parameters and variable radius orbit, all affecting SPECT resolution. Few data still exist on the comparison between filtered back-projection (FBP) and WBR. The aim of this study was to compare the performance of FBP and this new algorithm.

An anthropomorphic cardiac phantom with cold insert simulating regional infarctions was used to compare FBP and WBR; SPECT were acquired at standard time/frame (ST) and half time/frame (HT), with a standard isotope activity (SD) or with half activity (HD). The average FWHM of the simulated infarction of the cardiac phantom of SD-HT (65.7°) and HD-ST (57.5°) WBR SPECT were comparable to that of SD-ST FBP SPECT (65.3°). However, regional differences were observed.

Conclusions: The new reconstruction algorithm, applied to a cardiac SPECT acquisition, allows either for short time SPECT acquisitions or studies employing a reduced isotope activity. The former allows for an increased patient throughput and optimization of resources. The latter modality would also allow for a significant reduction in patients' as well as operators' radiation exposure.

1. Introduction

Myocardial perfusion imaging is the most worldwide used non-invasive technique for diagnostic evaluation and risk stratification of patients with known or suspected coronary heart disease. However, the increasing numbers of procedures raised some concern on the possible epidemiologic effects due to the increased population exposure (1 -2).

A new iterative reconstruction algorithm (Wide Beam Reconstruction, WBR, UltraSPECT Ltd, Haifa, Israel) has been recently proposed for cardiac SPECT. The WBR technology, based on an iterative OSEM method, incorporating an accurate modelling of the emission-detection process, was designed to reduce image noise improving lesion detectability without affecting the image resolution. Few data still exist on the comparison between filtered back-projection (FBP) and this new algorithm. In preliminary studies, it was documented the ability of WBR to provide images of the same quality of conventional FBP or iterative reconstruction methods, with reduced acquisition time (3). Before an implementation in the clinical setting, a fully evaluation in experimental models close to a real patient condition would be supportive.

Aim of this study was to compare the performance of WBR and FBP with different SPECT acquisition time and different isotope activity in a cardiac anthropomorphic phantom simulating myocardial infarctions in different regions.

2. Materials and methods

An anthropomorphic torso phantom consisting of a rigid elliptical torso made of hard transparent plastic was used. Lungs and a Teflon spine were inserted to simulate the nonuniform attenuation. The two lung spaces were filled with styrofoam, with a density similar to that of the lungs. The cardiac insert was double-walled with a 1-cm space between the walls. The myocardial walls, the right and left ventricular cavities, were filled with different solutions of ^{99m}Technetium mixed in water, while the remainder of the phantom was filled with water.

Two different isotope concentrations were used: one simulating the typical patients uptake of ^{99m}Tc-labeled tracers in a clinical settings for a standard patient of 70

Kg (approx. 100 kBq/cm^3 for myocardial walls, and 10 kBq/cm^3 for ventricular cavities) (standard dose, SD); and the second simulating the injection of half of the standard dose (half dose, HD). In both conditions, a solid insert (3.92cm^3, 60° aperture) was used to simulate a transmural infarction in anterior, septal, inferior, and lateral region.

2.1. Image Acquisition.

The torso phantom was placed on the patient bed of a gamma camera in a supine position. Particular care was taken to maintain the same phantom position with each acquisition. All acquisitions were performed with a dual-headed camera set in the 90° mode (Varicam VG, General Electric). The camera was equipped with a LEHR collimator (VPC45). Images were obtained in a 180° body-contouring orbit from the 45° right anterior oblique position to the 135° left posterior oblique position; 30 projections per head were acquired, in a 64x64 matrix, with a magnification of 1.28 and an angular step of 3°. For each wall activity and the different lesion positions, two sets of acquisitions were recorded: 20sec/frames (standard time, ST), and 10sec/frame (half time, HT).

2.2. Image Reconstruction and Analysis.

The acquisitions were reconstructed by conventional FBP and by the WBR algorithm. For the FBP reconstruction, a Butterworth filter (cutoff 0.4 cycle/cm and order 10) was used; no attenuation or scatter correction was applied.

An activity-vs-angular position histogram (circumferential profile, CP) from the short-axis slice that better displayed the lesion was obtained. For each acquisition and reconstruction method, the FWHM was calculated in each lesion, as an estimate of the insert angular aperture.

The defect contrast was also calculated as:

$$\text{contrast} = [\max(CP) - \min(CP)] / \max(CP)$$

where max(CP) and min(CP) were maximal and minimal counts in the CP, respectively (4).

Finally, the image contrast was calculated. Briefly, 2 regions of interest were drawn on the left ventricular wall and inside the cavity; the mean number of counts in the wall (m1) and the cavity (m2) regions was obtained. The contrast was calculated as: (m1-m2)/m1.

2.3. Statistical analysis.

Since each simulated cardiac lesion was acquired only one time for the different acquisition modality (acquisition time and activity), only average values were reported.

An ANOVA was used to compare the average FWHM and defect contrast in WBR and FBP reconstructed cardiac phantom studies. A p value < 0.05 was considered significant.

3. Results

The image contrast in SD-HT (72.3%) and HD-ST (74.2%) SPECT reconstructed with WBR was comparable to that of conventional SD-ST FBP SPECT (74.0%). The average defect contrast in SD-HT (47.8%) and HD-ST (49.7%) SPECT reconstructed with WBR was also comparable to that of SD-ST FBP SPECT (43.5%, NS), with a trend in a better defect contrast with WBR reconstructed SPECT, although regional differences according to the different lesion location were observed (Figure 1).

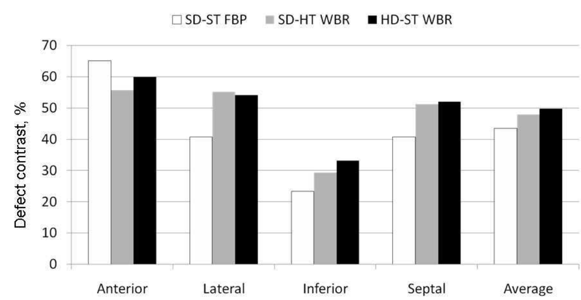

Figure 1. Bar graph showing the average and the regional defect contrast in the different acquisition modalities. HD= half-dose, HT= half-time, SD=standard dose, ST=standard time

Three representative short-axis slices with a defect in the anterior and septal region for SD-ST, SD-HT and HD-ST studies are reported in figure 2.

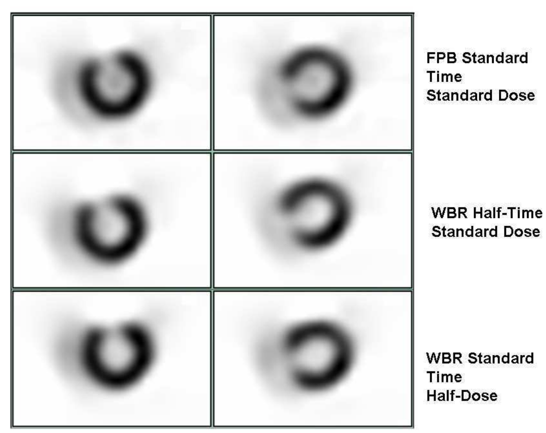

Figure 2. Representative short-axis slices showing a simulated infarction for the different acquisition modalities.

No significant differences were documented between FBP and WBR in the evaluation of the lesion amplitude as estimated by the FWHM (Figure 3). In particular, the average FWHM in SD-HT (65.7°) and HD-ST (57.5°) WBR SPECT were comparable to that of SD-ST FBP SPECT (65.3°). However, regional differences were observed in the FWHM, with the worst performance observed in the evaluation of the inferior defect for both FBP and WBR reconstructed SPECT (Figure 3).

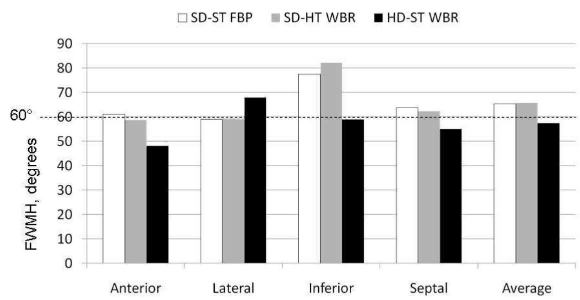

Figure 3. Bar graph showing the average and the regional estimated defect amplitude (FWHM, in degrees) in the different acquisition modalities. The true defect amplitude is also reported (dotted line).

4. Discussion

The WBR technology, unlike current SPECT reconstruction methods, does not assume the photon rays detected by the detector crystal to be perpendicular to it. Rather, it employs an iterative image reconstruction process that compensates for the non stationarity of the collimator's response ("beam spread function“ effect), takes into consideration the statistical behaviour of the emission and noise which may vary from one application to the other, and corrects for variation of the detector-to-patient distance according to a fixed or variable type of orbit. All this points play a role in the better resolution of WBR over conventional FBP reconstruction, and in the superior image contrast as already published by Borges-Neto et al (3). During the preliminary acquisitions to this work we obtained similar results with acquisitions setup according to NEMA standards, but we also obtain better WBR results compared to FBP during acquisitions simulating a conventional cardiac SPECT study, i.e. with camera settings comparable to those of a real patient study, and with different “3 lines” phantom positions taking in a count the differences of the relative positions between source location and the center of the angular range of sampling. Also in this conditions, WBR had a performance superior to FBP resulting in a better resolution.

In the studies acquired using the anthropomorphic cardiac phantom with an insert simulating a cardiac lesion, WBR resulted in comparable performance with respect to conventional FPB, either in half-time SPECT with a standard dose or with SPECT acquired at a standard time/frame but with half isotope activity, for different regional defects.

Moreover, in the present study, the cold insert simulating a myocardial infarction, was placed not only in the anterior position, but also in septal, inferior and lateral positions. Results confirmed the positive performance of WBR in a condition of low counts statistics, as those obtained in SPECT acquired at half time/frame or employing half isotope activity, in all defect position: the FWHM of the simulated regional infarction was comparable to that of FBP SPECT acquired at a standard time/frame and with a standard isotope activity.

5. Conclusions

The new reconstruction algorithm WBR, resulted in a better resolution when compared to conventional FBP. The quantitative analysis of a cardiac phantom study, indicated that the new reconstruction algorithm WBR compared well in respect to conventional FBP SPECT, allowing for both half-time or half-dose acquisitions with the same image quality. The former allows for an increased patient throughput and optimization of resources. The latter modality would also allow for a significant reduction in patients’ as well as operators’ radiation exposure. However, further studies are required to verify the clinical application of WBR (5)

References

[1] Einstein AJ, Moser KW, Thompson RC, Cerqueira MD, Henzlova MJ. Radiation dose to patients from cardiac diagnostic imaging. Circulation. 2007;116:1290-1305.

[2] Marcassa C, Bax JJ, Bengel F, Hesse B, Petersen L, Reyes E, Underwood SR, on behalf of the European Council of Nuclear Cardiology (ECNC), the European Society of Cardiology Working Group, (Nuclear Cardiology and Cardiac CT), and the European Association of Nuclear Medicine Cardiovascular Committee. Clinical value, cost-effectiveness, and safety of myocardial perfusion scintigraphy: a position statement. Eur H Journal, 2008;29:557-563

[3] Borges-Neto S, Pagnanelli RA, Shaw LK, Honeycutt E, Shwartz SC, AdamsGL, Coleman RE. Clinical results of a novel wide beam reconstruction method for shortening scan time of Tc-99m cardiac SPECT perfusion studies. J Nucl Cardiol 2007;14:555-65.

[4] Shotwell M, Singh BM, Fortman C, Bauman BD, Lukes J, Gerson MC. Improved coronary disease detection with quantitative attenuation-corrected Tl201 images. J Nucl Cardiol 2002;9:52-61

[5] Ficaro P, Hansen C, Cullom S, Tsui B. New reconstruction algorithms using limited angular sampling. J Nucl Cardiol 2006; 13:892.

Address for correspondence

O. Zoccarato
S. Maugeri Fnd, IRCCS
Scientific Institute of Veruno
V. Revislate 13, Veruno (NO) ITALY
orazio.zoccarato@fsm.it