Comparison of Single-Photon Emission Computed Tomography (SPECT) Half-Time Image Acquisition and Wide-Beam Reconstruction with Filtered Back-Projection: Sensitivity, Specificity and Accuracy in Diagnosis of Obstructive Coronary Disease

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Abstract

Background: Filtered Back Projection (FBP) has been used in single photon emission computed tomography (SPECT) imaging for decades. Half-time acquisition with wide-beam reconstruction (WBR) is a new technology that relies on resolution recovery, and has not been evaluated clinically.

Objective: To compare stress perfusion scores, diagnostic certainty and diagnostic accuracy of WBR and FBP in consecutive patients referred for clinically indicated gated SPECT.

Methods: 434 patients (63±13 yrs; 196 women, 238 men) referred for gated SPECT underwent stress Tc-99m sestamibi or tetrofosmin FBP (25 sec/stop) followed by WBR half-time (10 sec/stop) acquisition on a dual-detector 64-stop system (GE Millenium). Images were reconstructed by standard algorithm (QGS, Cedars-Sinai, Los Angeles, CA) for FBP, and by UltraSPECT (Haifa, Israel) for WBR. Summed stress perfusion scores (SSS) were based on a 5-point/17 segment model (0=normal tracer uptake to 4=absent tracer uptake). For all scans, perfusion was considered normal if SSS=0-1, equivocal if SSS=2-3, and abnormal if SSS≥4. Left ventricular myocardium defect in each of the coronary territories was quantified as $\%LV_{LAD,RCA,LCX} = SSS_{LAD,RCA,LCX}$ divided by maximal SSS for all segments in that territory (7 segments for LAD, max SSS_{LAD}=28; 5 segments for RCA and LCX, max $SSS_{RCA,LCX}$=20). Automated post-stress ejection

fraction (EF) calculations were reported. Paired t-test and Bland-Altman were used for SSS, %LV, EF. Kappa test was used to compare WBR and FBP for normal, equivocal and abnormal scans and for inter-observer agreement. A 2 group t-test was used to compare the magnitude of difference in $\%LV_{LAD,RCA, LCX}$ for FBP and WBR discordant and concordant scans. ROC analysis was used for angiographic correlation.

Results: SSS and EF and $\% LV_{LAD,RCA}$ were less for WBR than for FBP. Inter-observer agreement was good (kappa=0.78), and overall scan agreement moderate (kappa=0.49). WBR and FBP agreed fairly for SSS, EF, and $\% LV_{LAD}$ and poorly for $\%LV_{RCA, LCX.}$ There were fewer equivocal scans with WBR, likely due to a decrease in anterior attenuation artifact. The angiographic correlation revealed no difference for FBP and WBR in the detection of obstructive coronary disease.

Conclusion: WBR is a promising new technology that allows professionals to obtain high-resolution, diagnostically accurate images in half the time with improved diagnostic certainty over FBP.

Abbreviations: filtered back projection = FBP; wide beam reconstruction = WBR; summed stress scores = SSS; ejection fraction = EF; left ventricle = LV; left anterior descending = LAD; right coronary artery = RCA; left circumflex = LCX, single photon emission computed tomography = SPECT

Introduction

Approximately 7 million single-photon computed tomography (SPECT) perfusion studies are performed in the United States annually. Filtered back-projection (FBP) has been an established, standard method of reconstruction for myocardial perfusion SPECT for decades. There is a known trade off between sensitivity and resolution that is inherent

to the FBP. Such trade off adversely affects image quality and impacts diagnostic certainty and accuracy as well as laboratory efficiency. Recently, a number of technologies that rely on new computational methods have become available. Such iterative algorithms use resolution recovery methods that differ from FBP and ordered-subsets expectation maximization (OSEM) by considering the collimator response in image generation. That leads to a reduction of the effect of point-spread function on image resolution, and enables shorter scan times.

The clinical impact of such new technologies is not defined. Heller and colleagues reported that better image quality translates into improved diagnostic certainty while preserving diagnostic accuracy using shorter scan times with depth-dependent resolution recovery (Astonish, Phillips Medical Solutions) and attenuation correction. However, a trend for lower specificity and normalcy was observed for a new algorithm vs. FBP. In a recent report by Borges-Neto et al, evaluation in 50 patients revealed that one such novel algorithm, a wide-beam reconstruction (WBR) developed by UltraSPECT (Haifa, Israel) shortened scan time vs. FBP by half. The summed perfusion scores were not different for WBR and FBP, and qualitative and quantitative parameters were not compromised by half-time scanning. DePuey et al, using OSEM resolution recovery and WBR found that image quality increased significantly with WBR with lower post-stress ejection fraction (EF), primarily due to an increase in end-systolic volume. A quarter-time SPECT using WBR has been recently evaluated by the same investigators and found comparable to full-time OSEM for image quality.

While shorter scan times and better image quality have been reported in phantom and small sample patient studies, there is paucity of clinical data, and prospective

validation in large and clinically diverse patient groups is lacking. In particular, it is not known how improved image quality will affect perfusion scores and extent and severity of the regional perfusion defects. It is also not known whether there are differences by manufacturer.

We have prospectively evaluated 434 patients referred for clinically indicated gated SPECT with FBP and WBR (UltraSPECT, Haifa, Israel). The objectives were to compare perfusion scores and segmental defects, and diagnostic certainty as determined by consensus of two observers. Diagnostic accuracy was also determined in a subset of patients who were referred for invasive angiography.

Methods

Patient Population

Four hundred thirty four patients were referred to North Shore University Hospital, Manhasset, New York for clinically indicated gated SPECT between March 2008 and September 2008. The patients consisted of 196 females and 238 males. The mean age was 63 ± 13 yrs.

A subset of patients were referred for invasive angiography based on the results of the gated SPECT imaging.

Phantom Study

The phantom study was performed using the Jaczcak elliptical body with the cardiac insert (Data Spectrum Corporation). The phantom was setup using plastic inserts to simulate defects. Three inserts were used to mimic septal, anterior and inferior wall

defects. The central chamber of the phantom contained only water with no radioactivity added. Activity was added to the chamber used to simulate the myocardial wall and to the elliptical body to simulate background. The concentration ratio (myocardial wall to background) was approximately 3.5:1.

SPECT Imaging Protocols

Imaging Sequence. **:** 434 patients (63±13 yrs; 196 women, 238 men) referred for gated SPECT underwent stress Tc-99m sestamibi or tetrofosmin FBP (25 sec/stop) followed by WBR half-time (10 sec/stop) acquisition on a dual-detector 64-stop system (GE Millenium).

SPECT Image Analysis

Summed stress scores. Summed stress perfusion scores (SSS) were based on a 5-point/17 segment model (0=normal tracer uptake to 4=absent tracer uptake). For all scans, perfusion was considered normal if SSS=0-1, equivocal if SSS=2-3, and abnormal if SSS≥4.

Left ventricular myocardium coronary territory defect. Left ventricular myocardium defect in each of the coronary territory was quantified as $\%LV_{LAD,RCA,LCX} = SSS_{LAD, RCA, LCX}$ divided by maximal SSS for all segments in that territory (7 segments for LAD, max SSS_{LAD}=28; 5 segments for RCA and LXC, max $SSS_{RCA, LCX}$=20).

Statistical Analysis

Paired t-test and Bland-Altman were used for SSS, %LV, EF. Kappa test was used to compare WBR and FBP for normal, equivocal and abnormal scans and for

interobserver agreement. A 2 group t-test was used to compare the magnitude of difference in %LV$_{LAD,RCA, LCX}$ for FBP and WBR discordant and concordant scans. ROC analysis was used for angiographic correlation.

Results

Our analysis showed that SSS, EF and % LV$_{LAD,RCA}$ values overall were less for WBR than for FBP. WBR and FBP moderately agreed on SSS, EF, and % LV$_{LAD}$ and agreed poorly for %LV $_{RCA, LCX.}$ There were fewer equivocal scans with WBR, most likely due to a decrease in anterior attenuation artifact (Figure 1). Inter-observer agreement was good (kappa=0.78), and overall scan agreement moderate (kappa=0.49). The angiographic correlation revealed no difference for FBP and WBR in the detection of obstructive coronary disease (figure 3). Please refer to table 1 for a summary of results.

Figure 1: WBR decreases the attenuation artifact in the anterior wall that is commonly seen in the FBP images.
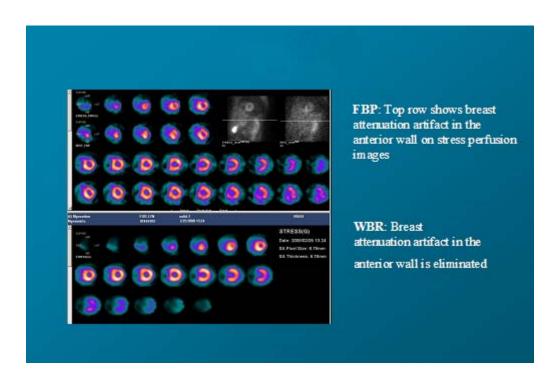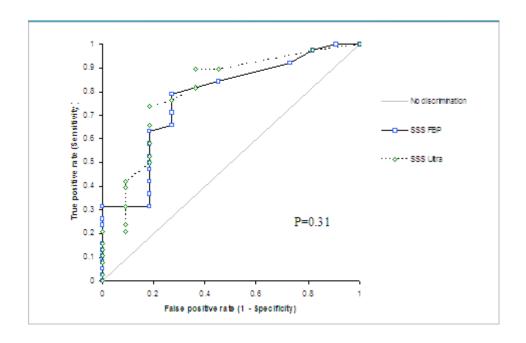
FBP: Top row shows breast attenuation artifact in the anterior wall on stress perfusion images

WBR: Breast attenuation artifact in the anterior wall is eliminated

Table 1: Statistical results

Scan	SSS	EF (%)	%LV LAD	%LV RCA	%LV LCX	Equivocal	Normal	Abnormal
FBP	4.8±0.37	59.4±0.67	7±0.7	9.4±0.9	6.8±1.5	153	162	119
WBR	4.2±0.39	57.8±0.63	5.3±0.7	7±0.8	6.6±0.7	36	284	114
Mean difference	-0.61	-1.57	1.6	2.3	0.2	p<0.0001 for all except %LV LCX		
Lower Limit Of Agreement	-4.8	-10.1	-14	-27	-57			
Upper Limit Of Agreement	3.6	7.0	11	22.2	57			
Δ discordant scans (WBR normal, FBP equivocal)			-3.5	-3.3	-1.1	P=0.0002 for %LV LAD		
Δ concordant scans (WBR, FBP both normal, abnormal, or equivocal)			-0.9	-1.9	-0.01	Inter-observer kappa=0.78		

Figure 3: Angiographic Correlation

The chart shows an ROC curve with "True positive rate (Sensitivity)" on the y-axis and "False positive rate (1 - Specificity)" on the x-axis. Legend: No discrimination, SSS FBP, SSS Ultra. P=0.31

Discussion

According to the data from National Health and Nutritional Surveys, coronary artery disease (CAD) affects approximately 13.7 million people in the United States and is the most prevalent form of cardiovascular disease (1). Non-invasive modalities to detect CAD are the most widely used form of diagnostic testing available, particularly gated cardiac single photon emission computed tomography (SPECT) perfusion imaging. SPECT provides the clinician with superior diagnostic capabilities and is ideal for quantitative analysis of the myocardium and its functionality (2). Filtered back projection (FBP) has been the standard in SPECT imaging. Wide beam reconstruction (WBR) is a newer modality which relies on resolution recovery and has shorter acquisition time (half-time).

In this study we aimed to study gated SPECT with FBP, the current standard and WBR, a novel algorithm. We compared summed stress perfusion scores and segmental defects. We found that SSS, EF and % $LV_{LAD,RCA}$ were less for WBR then for FBP. They agreed fairly for SSS, EF, and % LV_{LAD} and poorly for % $LV_{RCA, LCX.}$ When compared with FBP, WBR shortened scan time by half. Overall the summed perfusion scores were not different for WBR and FBP, and qualitative and quantitative parameters were not compromised by half-time scanning. There were fewer equivocal scans with WBR, likely due to a decrease in anterior attenuation artifact.

Diagnostic certainty was also compared as determined by consensus of two observers. Inter-observer agreement was good and overall scan agreement was moderate.

Lastly, a subset of patients underwent clinically indicated coronary angiography. The angiographic correlation revealed no difference for FBP and WBR in the detection of obstructive coronary artery disease.

Other papers comparing the two modalities have discussed similar findings although patient populations were not as large, DePuey et al included 156 patients and Hachamovitch et al included 50 patients. Currently there are no published studies to assess the diagnostic accuracy of SPECT imaging using WBR, in other words there are no other studies that include angiographic correlation.

In conclusion our data shows that WBR is a promising modality used in the detection of obstructive coronary artery disease. It is comparable to the current most widely used technology, FBP and allows us to obtain high-resolution, diagnostically accurate images in half the time with improved diagnostic certainty.

References

1. American Heart Association, Heart and Stroke Facts: 11995 Statistical Supplement. American Heart Association 1994. Dallas, TX 75231

2. DePuey EG, Berman DS, Garcia EV. <u>Cardiac SPECT Imaging</u>. New York: Raven Press; 1995.

3. Borges-Neto S, Pagnanelli RA, Shaw LK, Honeycutt E, Shwartz SC, Adams GL, et al. 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. DePuey EG, Gadiraju R, Clark J, Thompson L, Anstett F, Shwartz S. Ordered subset expectation maximization and wide bean reconstruction "half-time" gated myocardial perfusion SPECT functional imaging: A comparison to "full-time" filtered backprojection. J Nucl Cardiol 2008;15:547-63.