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Centering Artifacts Manifesting As Anterior Wall Defects On Myocardial SPECT Imaging

R Tello, T Hill, R Holmes, M Cohen

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Abstract

Purpose: During cardiac SPECT acquisitions in-vitro work has shown that artifacts that may be prospectively interpreted as anterior wall defects can be caused by body centered acquisitions rather than heart centered acquisitions. The purpose of this study was to quantify the effects of center of rotation (COR) placement at the heart, or body centered circular orbits in patients.
Methods: 44 patients underwent stress and rest Tc99m-Sestamibi SPECT myocardial scintigraphy using 20-30mCi (740-1070 MBq) and 8-10mCi (259-370 MBq) respectively (64 and 32 views at 30sec/view) using a Siemens Orbiter camera. All image data was evaluated by two radiologists blinded to each others readings. The raw projectional data was rated as body centered, heart centered, or in between using a nominal scale. The SPECT reconstruction data was interpreted for anterior wall defects on rest and stress images. Kappa statistic was calculated between observers and Maentel-Hentzel test for trend between number of anterior wall defects and increasing body centering in the COR of the SPECT acquisition was calculated.
Results: Kappa statistics demonstrated good (>0.70) agreement between observers. Analysis demonstrated increasing number of anterior wall defects as the COR moved from heart centered to body centered with an odds ratio of 2.5 [95%CI:1.09-20] for number of anterior wall defects in body centered vs. heart centered acquisitions at rest. In particular 2 cases with anterior wall defects had less cardiac centering on the rest images than the stress images on which these defects were no longer visible.
Conclusion: Increasing the distance between the COR of a SPECT acquisition and the anatomic center of the heart causes increasing anterior wall defects to be detected in vivo and may be contributing to artifacts in a daily clinical setting when using 180 degree acquisitions.

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INTRODUCTION

Compared to planar cardiac scintigraphic imaging, SPECT allows separation of superimposed myocardium and provides higher contrast images. Much work has demonstrated improved detection of coronary artery disease and improved localization of disease in specific coronary artery territories [1, 2, 3, 4, 5]. Nonetheless the complexity of SPECT makes it more prone to artifact creation than planar imaging. Attenuation by the breast, diaphragm, and right ventricle can be the origin of some of these artifacts. Other potential causes of artifacts include patient motion [6], respiratory motion, cardiac blurring in non-gated studies, and “upward creep” of the heart [7]. Instrumentation factors may also be the cause of artifacts due to center of rotation offset, flood nonuniformity, and nonlinearity of the detector, flaws in collimator construction, or mechanical inaccuracy of the gantry, which have all been reported to be possible sources of artifacts on Tl201 reconstructed slices [8, 9]. Additional work has also implicated the effect of detector orbit on artifact creation in-vitro using Tl201 [10].

In this paper we report the effect of the configuration of the orbit of the detector head around the heart during in-vivo SPECT imaging with Tc99m-MIBI. We observed increasing frequency of anterior wall defects as the orbit moved from a heart centered orbit to a body centered orbit.

METHODS

PATIENTS

Forty four consecutive patients over a two month period who were referred for myocardial stress scintigraphy with SPECT acquisition were retrospectively analyzed. Criteria for inclusion in the study included; the ability to safely undergo cardiac stress, no unstable angina, and no cardiac event or significant change in management between all scintigraphic studies.

IMAGING PROTOCOL

Informed consent was obtained after the procedure was fully discussed with each patient. The consent form was discussed with each patient and signed by them. Patients undergoing dypirdamole stress at 0.56 mg/kg abstained from any substances containing xanthines for 48 hr and fasted for 8hr. Vital signs and ECG were obtained prior to the examination. Preliminary rest scintigraphic images were performed in the nuclear medicine area under physician supervision. The patient was administered 7-10mCi (259-370 MBq) of Tc99m-sestamibi (Dupont, Billrica, MA) at rest and SPECT images were obtained on a single head camera (Siemens Orbiter, Hoffman Estates Ill) with a Strichman medical equipment 600 system (Strichman, Medfield MA) and a Macintosh IIVX (Apple, Cupertino, CA) were used to process the raw planar images. In those patients undergoing dypiridamole stress this was performed under physician supervision with blood pressure, pulse and ECG monitoring during the administration of 0.56 mg/kg dipyridamole over 4 minutes using standardized technique [11]. In those patients undergoing physical stress this was performed by a supervising cardiologist with a standard Bruce protocol [12]. Stress SPECT images were obtained 4 hours after resting studies after administration of 20-30 mCi (740-1070 MBq) of Tc99m-sestamibi using the same protocol as resting studies.

Tc99m-sestamibi images were obtained with the technique similar to that of Taillefer [13] using a 40 cm FOV rotating gamma camera (Siemens Orbiter, Hoffman Estates, IL) equipped with a low-energy, high-resolution parallel-hole collimator. Thirty-two images over 180 degree arc (30 sec per view for all images) were acquired from the right anterior oblique position to the left posterior oblique position at rest and 64 images were acquired at stress. Both stress and rest imaging data were reconstructed in short-axis, vertical long-axis, and horizontal long-axis tomograms using a 64x64 matrix. All studies were prospectively designed to be done as heart centered circular acquisitions with the heart at the center of the FOV on frontal and left lateral views.

STANDARD ANALYSIS

The SPECT data were re-evaluated prospectively by two other reviewers who did not know any of the other imaging results. The anterior wall, anterio-lateral wall, postero-lateral wall, posterior/inferior wall, and interventricular septum were each evaluated. Myocardial segments that demonstrated decreased activity in the stress SPECT study were labeled as perfusion defects. Abnormal walls were then further characterized as either reversible or fixed defects on the basis of the rest SPECT study. This was done by two blinded independent experienced readers where images were coned down to blind the observers as to the centering of a given study. Defects in the anterior wall were classified and separately analyzed, all of which were severe enough to be of clinical significance.

PLANAR ANALYSIS

The individual projectional planar raw data images were reviewed by two blinded independent readers and the stress and rest studies were classified separately as being heart centered (score 1), in-between (score 2), or body centered (score 3). A nominal scale was chosen rather than actual distance measures due to the differential body habitus between patients. Quality of SPECT studies was rated using a three point scale; 0=not satisfactory for diagnosis, 1=adequate image quality for diagnosis, 2=excellent image quality, where the difference between a rating of 1 and 2 was determined based on the belief that an image could be improved (1), or not (2). Quality of the studies was evaluated by two reviewers who were blind to the patients results and each others reading with kappa statistic measured[14]. In a heart centered study all the raw images viewed on a cine loop demonstrated the heart at the center of the gamma camera field of view (figure 1). In a body centered study all the raw images viewed on a cine loop demonstrated the central axis of the body at the center of the gamma camera field of view (figure 2). This can easily be checked by visual inspection of the cine display of the 32 or 64 planar images. If the heart is eccentric, it appears to “run” from one side of the screen to the other. In contrast, when the heart is in the center of rotation, the heart pivots in the center of the screen

Figure 1

Figure 1: Body centered camera orbit has the center of rotation of the camera (white cross-hair) at the center of the body contour.

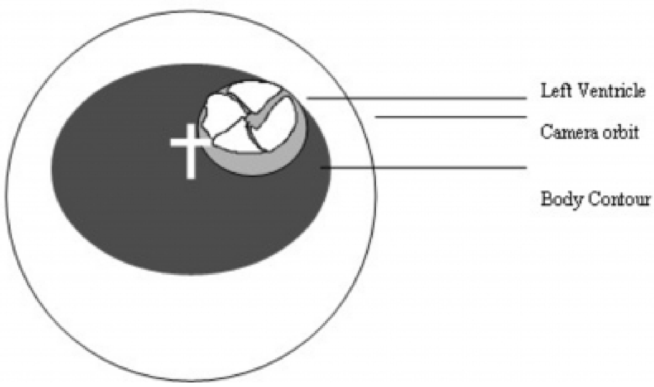
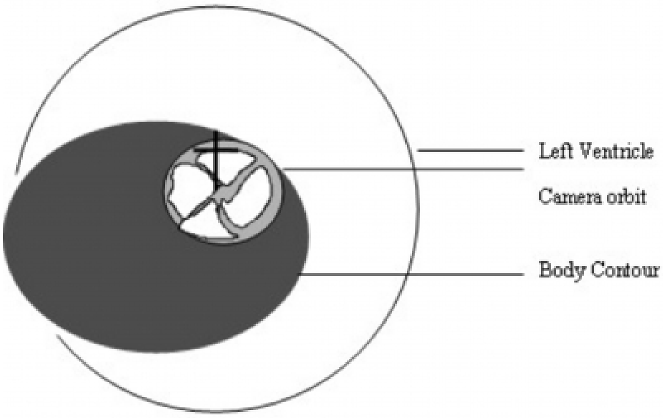


Figure 2

Figure 2: Heart centered camera orbit has the center of rotation of the camera (black cross-hair) at the center of the heart.



STATISTICAL ANALYSIS

The number of anterior wall defects in the 44 resting studies were stratified by the centering of the acquisition and a Mantel-Haenszel test for trend and odds ratio calculations were performed [15].

OBSERVATIONAL ANALYSIS

All studies were evaluated for fixed, reversible and discordant defects with correlation to the centering of the rest and stress acquisitions. A discordant defect is defined as an anterior wall defect present at rest but not at stress.

RESULTS

DEMOGRAPHICS

44 Subjects were examined, 22 males and 22 female. The mean age of these patients was 61 years (range:32-81). None suffered complications from the examination, and none of the dipyridamole stress (n=22) studies required aminophylline reversal.

IMAGE ANALYSIS

All SPECT studies were classified as diagnostic quality without motion or other artifacts. All raw planar images were rated as being without patient motion artifacts. Of the 44 rest studies 16 were classified as body centered, 19 as intermediate centered, and 9 as heart centered. This is delineated in table 1.

Figure 3

Table 1: Number of anterior wall defects during rest SPECT versus center of rotation (COR) placement.

COR placement	Anterior wall defects	Normal anterior wall
Heart centered	2	7
Intermediate	6	13
Body centered	8	8

OBSERVER AGREEMENT

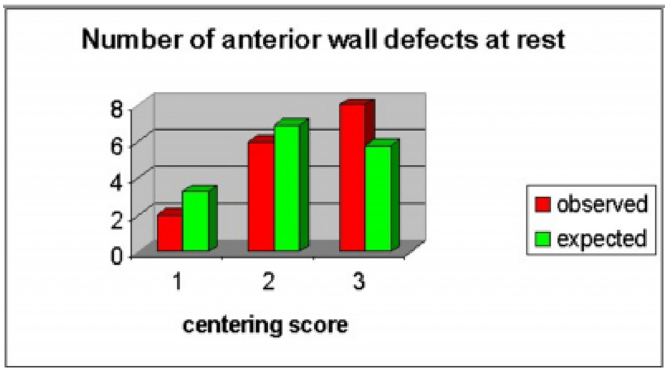
The Kappa statistic for rating of centering of study was 0.8-0.9. The Kappa statistic for rating of the presence of an anterior wall defect was 0.7-0.9.

CENTERING EFFECTS

Mantel-Haenszel test for trend suggested an association between study centering and the presence of anterior wall defects as shown in figure 3. There is a distinct increased number of defects as centering moves away from the heart compared to the expected number predicted under a null hypothesis. Odds ratio calculations demonstrated increasing number of anterior wall defects as the COR moved from heart centered to body centered with an odds ratio of 2.5 [95%CI:1.09-20] for number of anterior wall defects in body centered vs. heart centered acquisitions at rest.

Figure 4

Figure 3: Number of anterior wall defects detected compared to number expected if there was no COR effect. Scores are; heart centered (score 1), in-between (score 2), or body centered (score 3). Expected distribution is based on Chi squared distribution model.



DEFECT CLASSIFICATION

In particular 2 cases with anterior wall defects had less cardiac centering on the rest images than the stress images on which these defects were no longer visible.

DISCUSSION

The present study demonstrates that the artifact due to a body centered orbit is characteristic with dominant depression of anterior wall activity. In this analysis only the resting images were studied as the null hypothesis implies that the distribution of defects should be the same in each group. Whereas the stress images will have more defects due to underlying heart disease the confounding effects would require larger numbers for an adequate analysis. Reverse distribution as defined as a defect, either first appearing on redistribution Tl-201 images or appearing larger at redistribution has been defined by Soufer and they found that these defects correlated well with hybernating myocardium defined by 18FDG PET imaging[16]. One caveat in extension of this into reverse redistribution defects on Tc99m-Sestamibi SPECT is that if a defect is diagnosed during a body centered acquisition at stress and heart centered at rest then inappropriate referral for revascularization may be made. In Soufer's work they identified 15% of patients had reverse redistribution (for 44 patients this translates to 6-7 patients and for 4 territories this translates to 1-2 anterior wall defects, in line with our findings) their work was based strictly on planar imaging.

There are two ways in which this may be a significant problem in clinical Tc99m-SPECT imaging. Because of relatively low resolution of typical Tl201 SPECT studies the “body contour” orbit has been proposed and utilized in these patients. The detector head is brought as close as possible to the heart during a 180 degree rotation, thus depending on the ratio between the long and short axis, artifactual inhomogeneity described with Tl201 can also be seen with Tc99m-Sestamibi. The heart is in an eccentric position in the chest.

In order to avoid artifact rotational tomography should be performed with the heart in the center of rotation. In order to minimize the described artifact, we recommend careful positioning of the heart in the center of rotation of a 180-degree circular orbit for rotational tomography. In theory a 360-degree orbit might demonstrate less nonuniformity due to the averaging effect of opposite views.

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Author Information

Richard Tello, MD,MSME, MPH
Department of Radiology, Boston University school of Medicine

Thomas Hill, MD
Department of Radiological Sciences, Harvard Medical School, Deaconess Hospital

Roscoe Holmes, RRT
Department of Radiological Sciences, Harvard Medical School, Deaconess Hospital

Mylan Cohen, MD, MPH
Department of Radiological Sciences, Cardiovascular Division, Harvard Medical School, Deaconess Hospital