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Comparison Between Postprocessing Software and Repeated Scanning to Eliminate Subdiaphragmatic Activity in Myocardial Perfusion Scintigraphy

Daris Theerakulpisut, Chanisa Chotipanich[1]

Department of Radiology, Division of Nuclear Medicine, Khon Kaen University, Khon Kaen, [1]Division of Nuclear Medicine, National Cyclotron and PET Centre, Chulabhorn Hospital, Bangkok, Thailand

Abstract

Myocardial perfusion single photon emission computed tomography (SPECT) is a powerful test of evaluation for coronary artery disease, but subdiaphragmatic radiotracer activity often interferes with the interpretation of inferior wall findings. This study aims to evaluate the effectiveness of using software elimination of the subdiaphragmatic activity for the assessment of its efficacy in the correctness of image interpretation and the overall image quality of myocardial perfusion scintigraphy (MPS). MPS studies from January 2010 to October 2012 at our institution were reviewed. Thirty-two SPECT studies were included, all of which had significant subdiaphragmatic activity in the first scan and needed to be delayed to let the activity clear. Each scan was interpreted by using semiquantitative scoring in 17 segments according to the degree of radiotracer uptake. The first scan, which had interfering activity, was manipulated by masking out the unwanted activity with software native to our image processing software suite. The manipulated images were then compared with delayed images of the same patient, of which the subdiaphragmatic activity was spontaneously cleared with time. The first scan masked by software correlated with the delayed scan for myocardial regions supplied by the left circumflex (LCx) and right coronary artery (RCA), but not the left anterior descending (LAD). However, the quality of the masked scans was perceived by the observer to be better in terms of quality and ease of interpretation. Using software to mask out unwanted subdiaphragmatic activity has no detrimental effect on the interpretation of MPS images when compared with delayed scanning, but it can improve subjective scan quality and ease of interpretation.

Keywords: Myocardial perfusion scintigraphy, post-processing image manipulation, single photon emission computed tomography myocardial perfusion imaging, subdiaphragmatic activity

Introduction

Myocardial perfusion scintigraphy (MPS) is a well-established diagnostic nuclear medicine technique of study with high diagnostic and prognostic value for the evaluation of patients with suspected coronary artery disease.[1] Utilizing radiopharmaceuticals uptaken in the myocardium proportional to the coronary blood flow, myocardial perfusion can be imaged with single photon emission computed tomography (SPECT), and areas of myocardial ischemia can be identified as worse perfusion in the stress study than in the rest study.[2] One of the most commonly used radiopharmaceuticals for MPS is technetium-99m (^{99m}Tc)-sestamibi. As it is a technetium-based radiopharmaceutical, high-quality SPECT images can be obtained. However, one of the common artifacts encountered in sestamibi MPS is the presence of interfering subdiaphragmatic activity arising from the excretion of about one-third of the radiopharmaceutical via the hepatobiliary route into the intestine.[3] Subdiaphragmatic activity is detrimental to image interpretation as it can mask existing inferior wall perfusion defects due to scattering[4] and also conversely shows an apparent defect at the inferior wall due to the ramp filter artifact.[5] Additionally, the severity of subdiaphragmatic activity can cause problems

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Address for correspondence:
Dr. Daris Theerakulpisut, Department of Radiology, Division of Nuclear Medicine, Faculty of Medicine, Khon Kaen University, 123 Mittraparp Highway, Muang, Khon Kaen - 40002, Thailand. E-mail: daris.th@gmail.com

with image interpretation, which has been reported to occur in up to 6.6% of scans.[6] Hence, effective methods to reduce subdiaphragmatic activity have been investigated by many authors. Hurwitz *et al*. found that drinking water just before image acquisition helps reduce subdiaphragmatic activity.[7] Moreover, some authors have proposed milk consumption to help enhance clearance out of the hepatobiliary region, yet it has not proved to help in image interpretation.[8,9] If subdiaphragmatic activity is encountered in the initial image acquisition, the scan is usually repeated after a period of time to allow the subdiaphragmatic activity to clear.[8,10] Using postprocessing software, the final image can be manipulated to eliminate the subdiaphragmatic activity. Regions of interest (ROIs) can be drawn around the left ventricle and the activity outside of the ROI can be "masked" by the interpreting physician. Such methods are sometimes routinely done and some software applications automatically mask any activity outside of the left ventricle. Nonetheless, there have never been any studies to investigate the positive or negative effects of using such image manipulation in the interpretation of MPS. The purpose of the present study is thus to evaluate the effects of using software elimination in the subdiaphragmatic activity for the assessment of its effectiveness in the correctness of image interpretation and the overall image quality.

Materials and Methods

The study was approved by the Institutional Review Board of Srinagarind Hospital, Faculty of Medicine, Khon Kaen University. Patient consent was not obtained due to the retrospective nature of the study. All patient indentification was removed from every myocardial scintigraphic image.

Selection of MPS images

From January 2010 to October 2012, we retrospectively reviewed MPS studies done at our institution. MPS images with significant subdiaphragmatic activity prompting a delayed scan were included, regardless of the scan being a rest or stress study. Those with poor myocardial uptake or persistent subdiaphragmatic activity even after a delayed scan were excluded.

Image acquisition

With the patient placed in a supine position, MPS images were acquired after intravenous injection of approximately 7 mCi and 25 mCi of ^{99m}Tc-sestamibi for the rest and stress studies, respectively. SPECT was done using a step-and-shoot technique with 64 steps of 25 s each from the right anterior oblique (RAO) to the left posterior oblique (LPO) position. A low-energy, high-resolution collimator was used. The energy window was set at 20% around 140-keV photopeak with a matrix size of 64 × 64 × 16. Gating with electrocardiogram (ECG) was done using 8 bins per R-R interval.

Image processing

Using the AutoSPECT 3.5 software of the Phillips JetStream software suite, (Milpitas, California, USA) the MPS raw data were analyzed by a technologist and displayed as sequential tomographic slices in the short, vertical long, and horizontal long axes. For each of the included studies, three sets of images were obtained. The first image was the initial image with interfering subdiaphragmatic activity. The second was the delayed repeated image of the same patient after the cleared subdiaphragmatic activity. The third image was essentially identical to the first image except for eliminating the unwanted radioactivity around the heart using the mask-out function of the software [Figure 1]. The lung-to-heart ratio (LHR) was semiautomatically calculated by placing identical ROIs around the left lung and the heart. To assess the severity of subdiaphragmatic activity for more objectivity, a subdiaphragmatic activity-to-heart ratio (SHR) was also calculated in the same fashion as the LHR by placing the ROIs around the subdiaphragmatic activity and the inferior wall of the left ventricle [Figure 2].

Image interpretation

A nuclear medicine physician with more than 5 years of experience and blinded to the study performed the analysis of processed images and semiquantitatively scored each region of the myocardium according to the 17-segment polar plot with a score of 0-4, where 0 = normal uptake, 1 = mildly decreased uptake, 2 = moderately decreased uptake, 3 = severely decreased uptake, and 4 = absent uptake.[11] The quality of images was also subjectively assessed and each was given a score of 0-3, where 0 = excellent, 1 = good, 2 = fair, and 3 = poor. One month after the initial analysis, the same images were randomized and reanalyzed by the same nuclear medicine physician for the assessment of intraobserver variability.

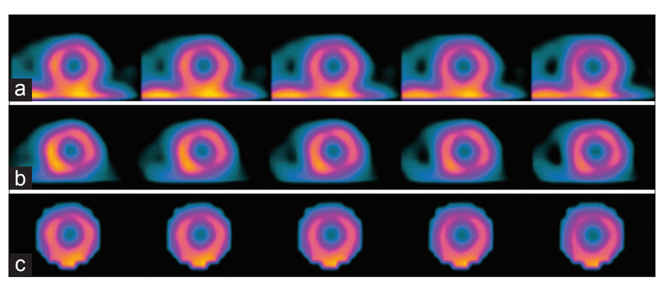

Figure 1: (a) The initial image with subdiaphragmatic activity; (b) The delayed repeated image of the same patient after the cleared subdiaphragmatic activity; and (c) The first image after elimination of the unwanted radioactivity around the heart using the mask-out function of the processing software

Statistical analysis

The demographic data as well as characteristics of the MPS studies were expressed as mean with standard deviation, and percentages. The scores in 17 segments were summed according to coronary vascular territory. Concordance correlation coefficients and percent agreement were calculated to assess for the agreement between myocardial uptake scores of the intial, delayed, and background subtracted images.

Results

From January 2010 to October 2012, there were 840 MPS studies done at our center. Among these, 40 images had to be repeated due to the presence of much subdiaphragmatic activity. Eight cases were excluded due to persistent subdiaphragmatic activity even after a delayed scan, leaving a total of 32 cases for analysis from 28 patients. Four patients had significant subdiaphragmatic activity in both the rest and the stress images, while the other 24 patients were found with significant subdiaphragmatic activity in only the rest or the stress study. Sixteen patients were female, aged 63.9 ± 10.8 years, and three patients (10.7%) had known coronary artery disease. The most prevalent risk factor in this cohort was hypertension (64.3%), followed by hyperlipidemia (39.3%) and diabetes mellitus (32.1%), as shown in Table 1. Among the 32 MPS studies included, 15 were rest studies (46.9%) and 17 were stress studies (53.1%). A vasodilatory pharmacological stress test with dipyridamole was used in the majority of stress studies (88.2%). The times to image acquisition for the rest and the stress studies were 66.90 ± 35.96 min and 54.93 ± 28.95 min, respectively. When the first acquisition yielded images with much subdiaphragmatic activity, as assessed by the attending nuclear medicine physician, a repeated delayed acquisition was ordered. The time from the first scan to the repeated scan was 78.16 ± 37.28 min. The calculated SHR revealed that the initial images had significantly more interfering subdiaphragmatic activity. For the rest of the images, the SHR was initially 1.17 ± 0.17 and was reduced to 0.81 ± 0.14 in the delayed repeated images. The initial stress images had a SHR of 1.13 ± 0.16 and was reduced to 0.69 ± 0.12 in the delayed repeated images. The summed myocardial uptake scores of the initial, masked, and delayed images were similar across the LAD, LCx, and RCA territories [Table 2]. When analysis for concordance of the myocardial uptake scores was done, we found that when comparing scores of the initial and delayed images, only the scores of the LCx and RCA had moderate concordance correlation coefficients of 0.463 and 0.407 respectively, while the scores of the LAD had poor concordance. Similarly, when comparing the masked and delayed images, moderate concordance was found for only the LCx and RCA territories with correlation coefficients of 0.407 and 0.489, while the LAD territory had poor concordance [Table 3]. The initial, delayed, and masked images were subjectively given scores of 0 (excellent), 1 (good), 2 (fair), or 3 (poor), based on their quality. Almost half of the initial scans were assessed as having poor image quality (46.9%). The delayed images showed the improved quality of 43.8%: That is, having excellent quality. The masked images received the best score of 68.7%, having excellent quality [Figure 3]. Intraobserver variability was also assessed as it might affect the reliability of study results. One month after interpretation, the nuclear medicine physician

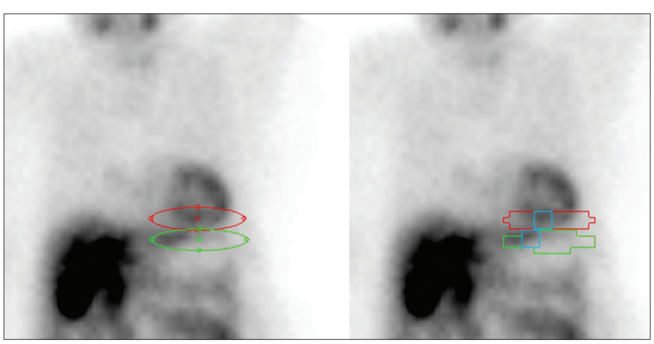

Figure 2: Semiautomatic quantification of the subdiaphragmatic activity as measured by the SHR by placing ROIs around the inferior wall of the myocardium and the most intense region of activity below the diaphragm

Table 1: Patients' demographic data

Age	63.9±10.8
Sex	
Male	12 (41.37%)
Female	16 (58.62%)
Known coronary artery disease	3 (10.71%)
Cardiovascular risk factors	
Hypertension	18 (64.28%)
Diabetes mellitus	9 (32.14%)
Hyperlipidemia	11 (39.28%)
Chronic kidney disease	4 (14.28%)
Smoking	3 (10.71%)

Table 2: The summed scores according to the three main coronary artery territories of myocardium in the initial, masked, and delayed images

Vascular territory	Myocardial uptake score		
	Mean	SD	95% CI
LAD initial	14.38	3.64	13.06 to 15.69
LAD masked	13.81	2.97	12.74 to 14.88
LAD delayed	12.59	3.45	11.35 to 13.84
LCx initial	8.53	2.91	7.48 to 9.58
LCx masked	8.66	2.81	7.64 to 9.67
LCx delayed	8.00	3.55	6.72 to 9.28
RCA initial	11.41	3.67	10.08 to 12.73
RCA masked	11.75	3.29	10.56 to 12.94
RCA delayed	10.88	3.33	9.67 to 12.08

SD: Standard deviation; CI: Confidence interval

Table 3: The correlation of summed myocardial uptake scores between the initial vs delayed and masked vs delayed scans across the three coronary artery territories

Vascular territory	Initial vs delayed					Masked vs delayed				
	Concordance correlation coefficient		Score difference		Limits of agreement (Bland-Altman)	Concordance correlation coefficient		Score difference		Limits of agreement (Bland-Altman)
	ρ	ρ	Mean	SD		ρ	ρ	Mean	SD	
Whole myocardium	0.080	0.626	2.844	8.762	−14.330 to 20.018	0.055	0.676	5.250	8.455	−11.321 to 21.821
LAD	0.306	0.038	1.781	4.062	−6.180 to 9.742	0.239	0.132	1.219	3.925	−6.473 to 8.911
LCx	0.463	0.001	0.531	3.341	−6.016 to 7.079	0.407	0.005	0.656	3.460	−6.126 to 7.439
RCA	0.407	0.007	0.531	3.801	−6.919 to 7.982	0.489	0.000	0.875	3.290	−5.573 to 7.323

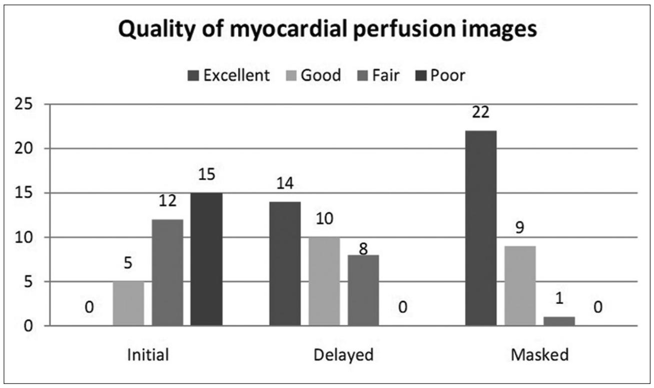

Figure 3: The quality of the initial, delayed, and masked myocardial perfusion images as subjectively assessed by the interpreting nuclear medicine physician and given a score of 0-3, where 0 = Excellent, 1 = Good, 2 = Fair, 3 = Poor

scored all images. Thirty images, 10 in each of the initial, delayed masked images, were randomly selected and sent for repeated scoring. Only the myocardium in the RCA territory had good intraobserver consistency in the initial, delayed, and masked image, with ρ values of 0.749, 0.764, and 0.619, respectively. The myocardium of the LCx territory had good consistency in only the delayed images, with a ρ value of 0.667. The myocardium in the LAD territory had very poor intraobserver consistency in the initial, delayed, and masked images [Table 4].

Discussion

MPS is a well-established imaging modality for the diagnosis of coronary artery disease; it also provides valuable information regarding prognosis and guides clinical management. However, many artifacts can complicate the interpretation.[5] About one-third of the radiopharmaceutical ^{99m}Tc-sestamibi is excreted via the hepatobiliary system,[3] resulting in subdiaphragmatic activity that complicates inferior wall interpretation. If enough subdiaphragmatic activity is present close to the inferior wall, a spurious perfusion defect may be noted due to the ramp filter artifact, that is, showing a false defect, or conversely the subdiaphragmatic activity can obscure the inferior wall, causing true defects to be missed.[5] Various ways to prevent or lessen the severity of this artifact have been investigated by several authors with varying results. At our institution, when an initial MPS image demonstrated significant interfering subdiaphragmatic activity, a delayed repeated scan was performed after about 30-60 min to allow the activity to move away from the heart. Most of the processing softwares used to analyze and display the MPS images possess the ability to mask out any unwanted activity that may interfere with the visual interpretation of images. However, there have been no studies to determine whether such methods to manipulate images in this fashion can have any detrimental effects on the overall image interpretation. This study compared the masked images with the delayed images to determine the myocardial uptake scores that can significantly differ from those of the delayed images to clear the subdiaphragmatic activity. From the completed 1620 scans, only 40 (2.46%) had significant subdiaphragmatic activity lower than the prevalence reported by Rehm *et al*.[6] This may be because the delayed scans in our study were performed to determine only severe subdiaphragmatic activity. Over half (53.1%) of the MPS images in this study were stress images. This was mainly due to the use of vasodilatory stress testing with dipyridamole in the study, as the majority of our patients were of advanced age and thus could not tolerate an exercise stress test. The time to image acquisition after radiopharmaceutical injection in this study was 67 ± 36 min for the rest scans and 55 ± 29 min for the stress scan, in accordance with the recommendation of the American Society of Nuclear Cardiology suggesting a 30-60 min wait for rest scans and 45-60 min for stress scans.[12] This indicates that the appropriate time for imaging may vary from patient to patient. The quantification of subdiaphragmatic activity in the images of this study revealed that the initial images had a SHR of 1.17 ± 0.17 and 1.13 ± 0.16 for the rest and stress images, respectively, which then decreased to 0.81 ± 0.14 and 0.69 ± 0.12 in the rest and stress images of the delayed scan, respectively. According to Pitman *et al.*,[13] the SHR of 1:1 or more could interfere with the interpretation of inferior wall, showing that the scans in our study maintained enough subdiaphragmatic activity to warrant concern and the delayed scans had enough

Table 4: The intraobserver variability of myocardial uptake scores for the initial, delayed, and masked images across the three coronary artery territories

Vascular territory	Concordance correlation coefficient		Pearson's correlation coefficient		Score difference		95% Limits of agreement (Bland-Altman)
	ρ	ρ	R	P	Mean	SD	
LAD							
Initial	0.048	0.891	0.048	0.894	0.000	3.682	−7.216 to 7.216
Delayed	0.111	0.736	0.118	0.746	−1.000	4.667	−10.146 to 8.146
Masked	−0.265	0.414	−0.268	0.453	0.200	4.104	−7.844 to 8.244
LCx							
Initial	0.360	0.178	0.416	0.232	1.100	2.558	−3.914 to 6.114
Delayed	0.667	0.000	0.847	0.002	2.200	1.751	−1.232 to 5.632
Masked	0.253	0.304	0.345	0.329	2.100	2.961	−3.703 to 7.903
RCA							
Intial	0.749	0.000	0.754	0.012	0.400	2.633	−4.761 to 5.561
Delayed	0.764	0.000	0.785	0.007	0.000	2.789	−5.466 to 5.466
Masked	0.619	0.001	0.759	0.011	2.200	2.486	−2.672 to 7.072

improvement over the initial scan to be used as a reference for comparison. The myocardial uptake was scored for each of the 17 segments, and then summed according to the coronary artery territory where the LAD comprised of segments 1, 2, 7, 8, 13, 14, and 17. The LCx consisted of the segments 5, 6, 11, 12, and 16, while the RCA consisted of segments 3, 4, 9, 10, and 15. The concordance of the the scores was calculated according to the vascular territories to reflect routine practice, and found only between the summed myocardial uptake scores of the LCx and RCA territories when comparing the initial and delayed images and the masked and delayed images. The myocardium of the LAD territory showed poor concordance when comparing between the initial and delayed images and the masked and delayed images. The finding was indeed unexpected, as the LAD territory was farthest from the interfering subdiaphragmatic activity, which might be due to the LAD territory being comprised of seven myocardial segments, larger than only five myocardial segments each of the LCX and RCA. This resulted in greater variation when comparing two sets of myocardial uptake scores between the initial and delayed images, the masked and delayed images, or even in the intraobserver variability analysis. The assumption could be supported by the fact that the concordance between summed myocardial uptake scores of the 17 segments—0.080 when comparing the initial and delayed images, and 0.055 when comparing the masked and delayed images—was even lower than that of the separate territories. By masking out the unwanted subdiaphragmatic activity, the interpreting nuclear medicine physicial perceived the quality of images to be much better than the initial images with the interfering activity and even the delayed images. This may be because masking out the unwanted activity could help the interpreter to focus on only the myocardium. Using the postprocessing manipulation of images in this fashion may improve the image quality but may also make the interpreter unaware of the significant subdiaphragmatic activity, causing artifactual defects or obscuring true defects. However, as our study found no difference when comparing between the initial and delayed images and masked and delayed images, we concluded that using masking of the MPS images did not cause any detrimental effects on the interpretation of MPS images. Although not mandatory, this could significantly improve image quality and ease of interpretation. Nonetheless, there were several limitations in this study. The retrospective nature of our study raised the possibility that the initial and delayed scans might not have been identically performed in terms of patient positioning and the distance of the detector, which could adversely affect the intraobserver variability and also the concordance of myocardial uptake scores. In addition, most of our patients were of low cardiovascular risk, and thus most of our MPS resulted in normal scans. Further prospective study should be done in which variables between the initial and delayed scans can be controlled in patients with abnormal MPS findings and the interpretation of myocardial uptake scores are more difficult. It should be stressed that manipulating the images in this fashion does not eliminate any true artifacts that might be caused by subdiaphragmatic activity. In cases with very severe subdiaphragmatic activity, a delayed scan is still mandatory. In conclusion, despite some limitations in this study, our data reveal that using software to mask out unwanted subdiaphragmatic activity has no detrimental effects on the interpretation of MPS images when compared with delayed scanning but can improve subjective scan quality and ease of interpretation.

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