Correlation of automatic processing method in myocardial perfusion SPET with the interactive method

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Abstract

Different techniques have been introduced for full automatic processing of myocardial perfusion imaging with single-photon emission tomography. We tried to evaluate the accuracy of one of these commercial automatic processing methods. *The study was performed* in 300 patients during 18 months. Two post-stress acquisitions in supine and prone positions and one acquisition at rest , were performed for every patient. All images were processed both automatically and interactively and the results were compared to each other. *The automatic method matched* the interactive method in 95.22% for left ventricle isolation, in 99.54% for excluding extra-cardiac activity and in 98.22% for reorientation of a single projected data. The automatic method was also successful in complete processing of 81.33% sets of stress (supine)-rest and 79.77% sets of stress (prone)-rest images as compared to the interactive method. *In conclusion*, the fully automated processing method matches the interactive method in complete processing of myocardial perfusion imaging with single-photon emission tomography more than 79.77% and is of equal accuracy to the interactive method in supine and prone-positioned acquisitions.

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Introduction

Myocardial perfusion imaging (MPI) with single photon emission tomography (SPET) is the most frequently performed study in nuclear cardiology [1]. Most myocardial perfusion SPET images are viewed in a standard format, consisting of short-axis (SA), horizontal long-axis (HLA) and vertical long-axis (VLA) slices. Short-axis slices are also necessary for some automatic perfusion quantification algorithms. Generation of these standard sections from the original transaxial images, has been performed interactively, requiring the user to mark the location of the left ventricular axis [2]. In this method, the long axis of the left rentricle (LV) is defined as the line between the apex of the LV and mid-mitral valve and, if performed automatically, the processing should be checked for accuracy. It is obviously essential that this axis is the same between stress and resting images. Three sets of images of HLA, VLA and SA are then constructed. The horizontal long axis is a plane through the LV to incorporate the septum, lateral wall, and apex in the shape of a horseshoe. The vertical long axis is the plane through the LV incorporating free anterior wall, inferior wall, and apex. The short axis views are perpendicular to the long axis views and show the LV as a ring except towards the base, when the myocardium becomes crescent shaped [3].

In the past few years, automatic techniques for performing this task have been described and are commercially available. The approach to the full automatic processing usually includes LV isolation, reconstruction and reorientation [2].

In this article we have tried to evaluate the accuracy of one of these commercial automatic methods, which is used in MyoSPET application of VISION® Powerstation (Version 6.0.0) GE Medical system to provide standard final images in myocardial perfusion SPET study in both supine and prone positions, in comparison to the interactive method.

Materials and methods

We performed a cross-sectional study on 300 patients in our department over a period of 18 months from January 2005 to August 2006. The mean age of our patients was 56.77±11.34 years. Of this population, 175 (58.3%) were female and 125 (41.7%) were male. The study population adults, admitted to perform a MPI SPET study for coronary artery disease (CAD). The patients had no evidence of transmural myocardial infarction. All patients gave their informed consent and signature. A two-day technetium-99m-^{99m}Tc ^{99m}Tc-sestamibi stress-rest protocol was performed with an injection dose of 740MBq in each phase of the study. The post-stress images were obtained either after exercise (124 cases; 41.33%) or administration of pharmacologic agents (176 cases; 58.67%), according to standard protocols [4]. The post-stress acquisitions were obtained with patients lying in both supine and prone positions. The rest phase acquisitions were performed with patients lying only in the supine position.

A series of three acquisitions, comprising two post-stress acquisitions in supine and prone positions and a single supine-positioned rest phase acquisition, were performed for each patient. All acquisitions were performed in SPET mode by a GE DST-Xli (USA) dual-head gamma camera, equipped with low energy-high resolution (LEHR) collimators. For each study, 32 projections of 30 sec each, were acquired with 64x64 matrix size and 1.33 zoom factor in a circular 180-degree arc around the patient (45 degree RAO-to-LPO). All images were reconstructed by a nuclear physician (H.M.) both interactively and automatically, using MyoSPET application of VISION®POWERstation (Version 6.0.0) GE Medical system. The reconstruction filter of Metz (psf FWHM of 5 and order of 8) was applied as the default filtration for all studies. In case of the presence of extra-cardiac hot activity, masking was also performed in the interactive reconstruction method, using 3D elliptical masking option. All cine images were controlled visually and those studies with motion artifacts or low-count density, were excluded.

The angle of the LV long-axis was calculated on both trans-axial and sagittal images in every set of images. Inability to localize the LV, presence of significant hepatic or intestinal activity in the LV region of the image, rendering to extra-cardiac normalization, greater than 20-degree difference between automatically and interactively determined axes or greater than 10-degree difference between post-stress and rest orientations, were all considered as failure criteria for the automatic processing method.

Data were expressed as mean values ± standard deviation (SD). The X square test was used to compare the differences, using SPSS 13 software package (SPSS Inc., Chicago, IL, USA). A P value <0.05 was considered as statistically significant.

Results

Among the total 900 acquisitions, 48 (5.33%) of the images could not be processed automatically, either due to software inability to determine the LV myocardial boundaries correctly (43 acquisitions) or to the presence of significant hepatic or intestinal activity in the LV region, resulting in extracardiac normalization (5 acquisitions). On the other hand, the software determined the LV myocardial boundaries correctly in 852 acquisitions (95.22%).

Sixteen (1.78%) of processed acquisitions were considered as failure of the automatic reorientation method due to differences greater than 20 degrees between automatically and interactively-determined axes. Most of these differences occurred on the transaxial (14 acquisitions) as compared to the sagittal plane (2 acquisitions).

The failure of fully automatic processing method due to greater than 10-degrees difference between the stress and rest orientations, occurred in 11 (3.67%) sets of stress (supine)-rest and in 26 (8.67%) sets of stress (prone)-rest images in the transverse plane. The comparative data on the sagittal plane were 12 (4.00%) and 29 (9.67%), respectively. These cases were considered as the failure of automatic processing method as mentioned before.

On the whole, the automatic method was successful in 246 (81.33%) sets of stress (supine)-rest and 239 (79.77%) sets of stress (prone)-rest images, demonstrating no significant statistical difference between the two positions (P<NS). An example of automatic processing, including left ventricle isolation, reconstruction and reorientation is seen in Figure 1.

The automatic method was also successful in 143 (81.71%) sets of stress (supine)-rest and 138 (78.85%) sets of stress (prone)-rest images in females and in 103 (82.40%) sets of stress (supine)-rest and 100 (80.00%) sets of stress (prone)-rest images in males, demonstrating no significant statistical difference between males and females (P<NS).

Discussion

While processing a SPET perfusion study, incorrect assignment of the left ventricular long-axis on either the midtransaxial or mid-ventricular long-axis slices, may result in

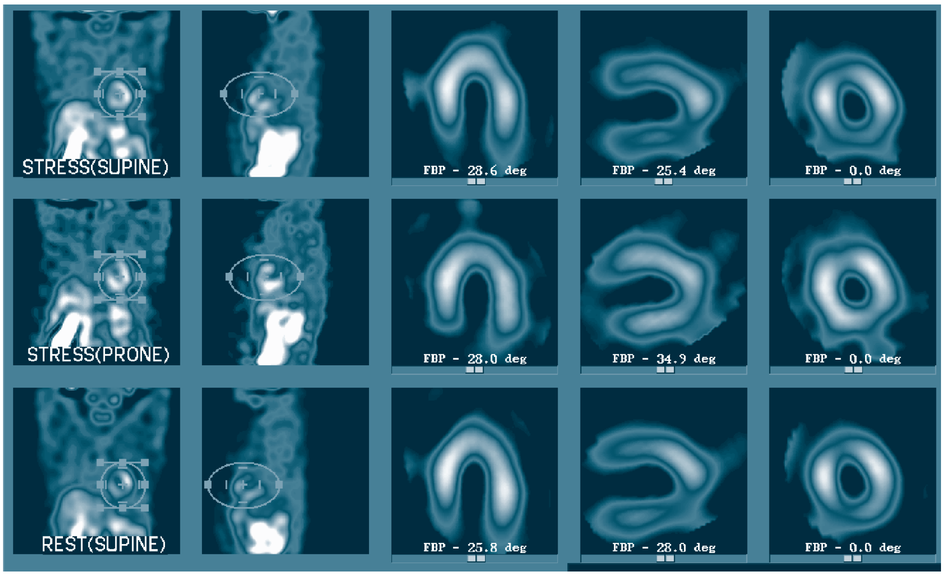

Figure 1. An example of automatic processing. Upper row: stress images in supine position; Middle row: stress images in prone position; Lower row: rest images.

reconstructed slices that are distorted and not comparable. This is known as artifacts caused by reconstruction [5]. We have taken care so as long-axis orientation lines were parallel to long-axis walls of the myocardium and consistent between rest and stress images. Inappropriate plane selection can result in incorrect interpretation [6].

In the past two decades, both image quality and clinical utility have been greatly improved with major advancements in automated quantification and display, including completely automatic reconstruction and slicing [2]. At the same time, the accuracy and reproducibility of these methods have also improved [7]. Different algorithms have been developed for completely automatic generation of reoriented tomographic images from the projections of the myocardial perfusion SPET, usually including left ventricle isolation, reconstruction and reorientation.

In one study, a completely automatic technique was developed to reorient transaxial images into short-axis myocardial perfusion SPET images [8]. "That algorithm starts by isolating (segmenting) the LV myocardium using a combination of iterative clusterification and rule-based location/size/shape criteria. The three-dimensional, mid-myocardial LV surface was initially estimated as the locus of the tri-linearly interpolated maxima for the count profiles originating from the center of mass of the segmented LV. The final mid-myocardial surface was obtained by iteratively applying this process, incorporating additional constrains of shape and texture and using the non-segmented, non-thresholded transaxial image to obtain information on hypoperfused areas of myocardium. It is then fitted to an ellipsoid, of which the major axis is assumed to represent the long-axis of the LV and the three-dimensional image volume is re-sliced perpendicularly to it". This method was tested on 400 patient's images, and the result compared to the interactively denoted long-axis. The method was successful in 394 of the 400 cases (98.5%) [8]. However, greater than 45-degree differences between automatically and interactively determined axes were assumed as failure criteria in this study. As we set the orientation of interactively reconstructed images by an expert user as the reference views, we assumed that the difference between automatically and interactively reconstructed images should be less than 45 degree in clinical practice. Therefore we chose a maximum 20-degree (i.e. ±10 degrees in each direction) difference as a parameter for acceptable automatic reorientation, which can explain the cause of less successful complete automatic processing in our study (81.33% vs. 98.5%).

In another study, three software modules were used as the automated algorithm [9]. "The first module determines reconstruction limits for the projection dataset using two-dimensional feature extraction techniques. The second module reconstructs the projection images into transaxial images using standard filtered backprojection and the third module reorients the transaxial images into short-axis images". This algorithm was validated on 350 rest thallium-201 and 360 stress ^{99m}Tc-sestamibi studies and the complete processing sequence was successful in 93.6% of the studies. In their study, the myocardial boundaries were correctly determined in 96.3% of the studies, while the orientation was successful in 97.2% of the studies [9]. Although we achieved comparable results in the correct determination of the LV myocardial boundaries (95.22% Vs 96.3%), complete automatic processing was less successful in our study (81.33% vs 93.6%), apparently due to higher failure in reorientation.

Another more complex heuristic technique was used by another group of authors to determine the optimal LV threshold and isolate it from other structures [10]. "After this is accomplished, they used the segmented data directly to determine the long axis. The binary image is tessellated into triangular plates, and the normal of each plate on the endocardial surface is used to "point to" the LV long axis. The intersections of these normal (or near-intersections) are collected and fit to a three-dimensional straight line, which is then returned as the LV long-axis. This method was tested on 124 datasets, and the automated long-axis orientation was compared to interactively determined angles". Failure was described as a failure to isolate the LV, and this method was succeeded in 116 out of 124 cases (93.55%) [10], which is comparable to our finding (95.22%). We have excluded patients with previous myocardial infarction; however, it is possible that greater differences will appear between the two methods in patients with myocardial infarction

In conclusion, the fully automated processing method is an important step towards totally less operator management of myocardial perfusion SPET data either in supine (81.33%) or prone (79.77%) positions and is of equal accuracy between males and females.

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