3D Spect Myocardial Volume Estimation Increases the Reliability of Perfusion Diagnosis

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Abstract

The aim of this work consists of modeling the left ventricle of the heart, at stress and rest situation, using the myocardial scintigraphic data obtained in 3D stress/rest images and focuses on the possibility of quantification of differences. 32 cardiac patients completed stress and rest tests by Tc99m tetrofosmin in one-day protocol by a GE-Starcam-4000 gamma-camera; Images of myocardium were reconstructed by the GE Volumetrix software in the GE Xeleris processing system. Myocardial perfusion was estimated by all (Short axis, HLA (Horizontal Long Axis) and VLA (Vertical Long Axis)) SPECT slices. For each patient, 2 series of transverse slices by tomographic image reconstruction, were produced, using OSEM iterative algorithm. DICOM data was extracted for each patient and an algorithm that integrates 3D visualization has been used for image processing analysis by MatLabR2012b. The appropriate threshold value was identified by creating intensity isocontours. The myocardium volume was evaluated and reconstructed as 3D image and calculations of the differences between the rest and stress data of the 3D images were made. An index ratio of the Volume of Interest (VOI) was determined. The differences between 3D images at rest and stress situations provide us with visual and quantitative evaluation of myocardial perfusion.

Key words: 3D SPECT, myocardial scintigraphy, MatLab volume reconstruction

Introduction

Heart is the most vital organ for normal functioning of the human body. The left ventricle of the heart is the chamber that is responsible for pumping oxygenated blood to various parts of the body. The ability of the heart to function effectively and to ensure adequate supply of blood and nutrition to the various parts of the body depends mostly on the integrity of the left ventricular (LV) myocardium [1-2].

Coronary Artery Disease (CAD) is caused by the accumulation plaque along the inner walls of one or more of the three main coronary arteries of the heart or their branches, which supply blood to the LV myocardium. As a result, this plaque causes narrowing or occlusion of the arteries and reduces blood supply of the myocardium. In the early stages of CAD, the reduced blood flow might be enough to meet the metabolic demands of the contracting myocardium at rest. However, when stressed (or even at rest when the disease has been progressed) the reduced blood supply leads to a supply-demand mismatch to the myocardium, a condition known as myocardial ischemia.

Early and accurate diagnosis of ischemic heart disease (caused by CAD) can potentially reduce mortality and morbidity in patients. This can be achieved by identifying LV regions that could be revascularized, before the corresponding myocardium is irreversibly scarred. In the majority of cases, this could lead to complete recovery. Thus, estimating the affected area of the myocardium is a very important achievement for patients with coronary artery disease.

Assessment of cardiac performance is markedly enhanced by a quantitative description of the specific physiologic parameters evaluated by single-photon computed tomography scintigraphic images (SPECT Myocardial Perfusion) [3].Estimating the affected area of the myocardium is a very important achievement in patients with CAD. A common approach for the diagnosis of myocardial ischemia with underlying CAD is cardiac stress testing. This is achieved by stressing the heart either with physical exercise or artificially with pharmacologic agents [4].The SPECT study consists of several frames which, together, can sample the blood perfusion of the heart muscle in three dimensions [3].The quantification of the SPECT studies enables objective interpersonal comparison and objective assessment of cardiac status. Furthermore, computer algorithms extract parameters of cardiac performance so that eventually can be precisely described. Our approach is based on the generation of 3D images of two distinct phases the patient undergoes in the SPECT study: rest and stress protocol. The rest protocol shows the patient's myocardium state when he is resting on a bed and the stress protocol when the patient's heart is stressed as mentioned above. By comparing the stress and rest 3D images it is possible to identify the abnormal perfusion defects.

Materials and Methods

Stress SPECT involves the evaluation of myocardial perfusion abnormalities resulting from externally induced stress. 32 cardiac patients had completed stress (^{99m}Tc tetrofosmin at stress peak) and rest tests in one-day stress-rest protocol by a GE – Starcam – 4000 – tomographic – gamma - camera. Tetrofosmin labelled with ^{99m}Tc, after intravenous injection, follows the regional blood flow distribution. After time duration equivalent to ^{99m}Tc half-life, the radionuclide transits to a more stable chemical form through the process of electron capture. The photons emitted in the process are detected by special gamma sensors, which produce the output signal that is measured. The intensity of digital signal detected in SPECT is proportional to the regional blood flow.

According to the basic clinical stress SPECT protocol, the patient initially undergoes either exercise stress or pharmacological stress. Then, the patient is given an intravenous injection of 740 MBq (20 mCi) ^{99m}Tc tetrofosmin at peak stress. Post-stress imaging usually starts 20 minutes after injection of Tc-99m tetrofosmin, as this compound is remotely redistributed (about 20%) within the first 20 to 60 minutes following injection. Two hours later a new quantity of ^{99m}Tc-tetrofosmin is injected to the patient and post - injection images are acquired after a 20 minutes delay.

The acquisition images are reconstructed. Ordered Subsets Expectation Maximization (OSEM) reconstruction technique is used to reconstruct our 3D images for diagnosis. Tomographic image reconstruction in a SPECT GE – Starcam -4000 – tomographic – gamma - camera produces a series of parallel transverse images, or transaxial images, perpendicular to the long axis of the patient. However, the angular orientation of the left ventricle in the thorax varies among patients. Orientation of the LV myocardium is detected and the LV central long axis and the apex are placed in default positions as shown in figure 1.

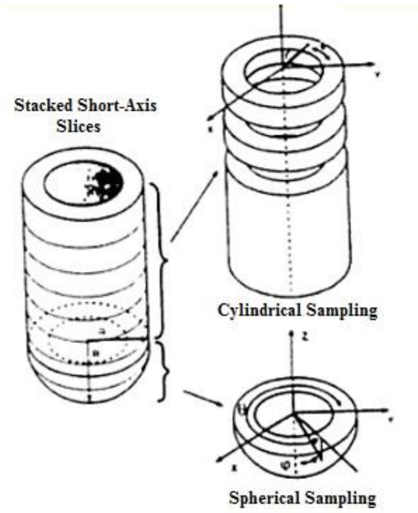

Figure 1: Orientation of the LV myocardium is detected and the LV central long axis and the apex are placed in default positions.

Reorientation of the transverse images to cardiac short-axis slices that are perpendicular to the long axis of the left ventricle is performed, in order for the SPECT data to be quantified. The left ventricle central long-axis vector determines the orientation of perpendicular short-axis slices needed for conventional cardiac imaging (Figure. 2).

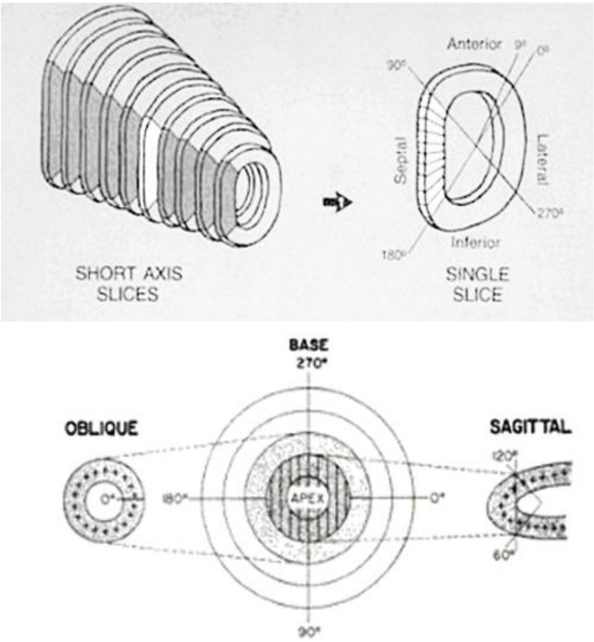

Figure 2: Left ventricle central long-axis vector determines the orientation of perpendicular short-axis slices needed for conventional cardiac imaging.

We used the data of the two sets (stress-rest) of SPECT slices. Thus, the myocardial perfusion was estimated by comparing these slices and suspicion of ischemia was indicated (Figure 3).

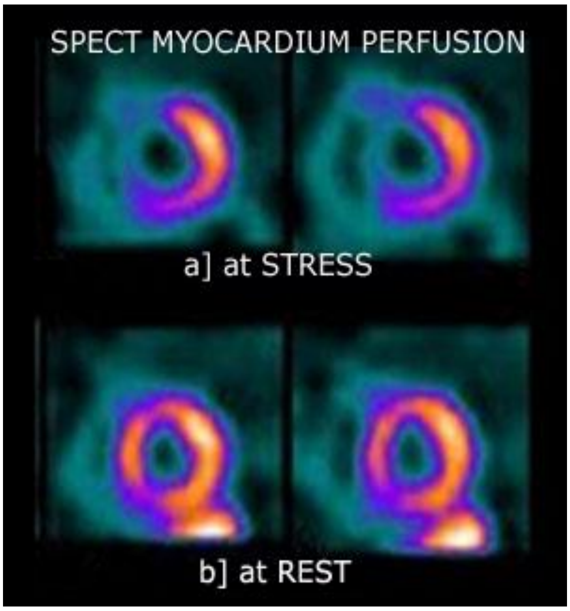

Figure 3: Two sets (stress-rest) of SPECT slices.

2 series (stress – rest) of transverse slices of myocardium images for each patient were reconstructed by the GE Volumetrix software in the GE Xeleris processing system. OSEM iterative reconstruction technique and a butterworth frequency 0.4 filter were used.

2.1 Isocontour surfaces for threshold value determination

Images were extracted in a DICOM format. The DICOM file for each patient and each phase is imported to MATLAB 7.8 (R2009a). A series of isocontour surfaces are studied, in order to identify the appropriate threshold value, which isolates the myocardium surface from the rest area (background) of the image. The following example shows the functions used for constructing the isocontour surfaces of the 9th transverse slice of myocardium stress images.

Example 1

```
SPECT=dicomread('G:\STRESS_IRNC001_DS.dcm');
I=SPECT(:,:,1,9);
imagesc(I);
C=contour(I);
clabel(C);
```

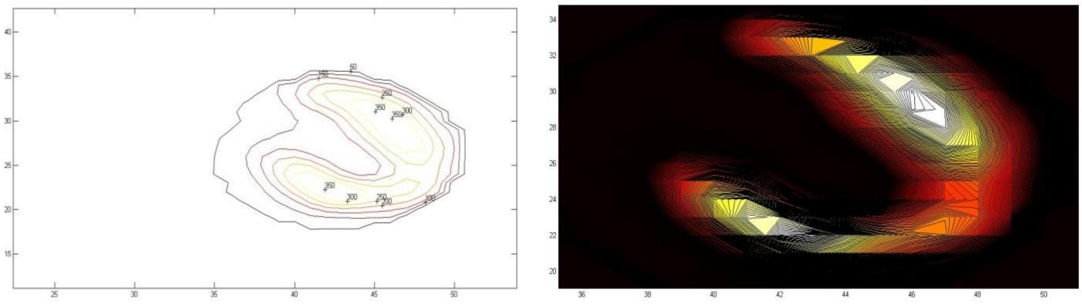

Figure 4: Isocontour surfaces for threshold value determination; REST

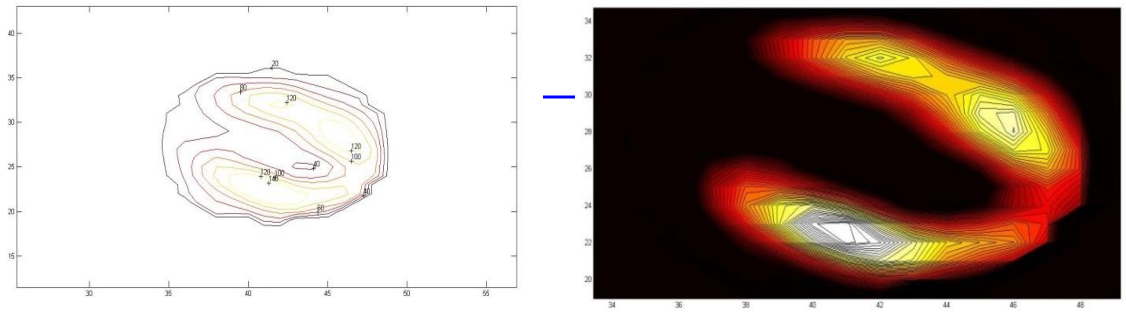

Figure 5: Isocontour surfaces for threshold value determination; STRESS

2.2 Intensity volume and 3D visualisation

Volume visualisation in nuclear medicine is a method of extracting information from volumetric data utilising and processing a nuclear medicine image [5].In MatLab, this can be achieved by constructing a 3D surface plot which uses the pixel identities for (x, y) axes and the pixel value is transformed into surface plot height and consequently, colour. Apart from that, 3D voxel images can be constructed; SPECT projections are acquired, iso-contours are depicted on them including a number of voxels and, finally all of them can be added in order to create the desirable image [6].

In this study, based on the previously calculated threshold value, the myocardium volume is evaluated and reconstructed in a 3D image. Example 2 indicates the functions for the 3D image reconstruction (where 40 is the value of the calculated threshold value).

Example 2

```
mask=logical(zeros(64,64,19));

for k=1:19
   for i=1:64
      for j=1:64
         if (SPECT(i,j,k)>40);
            mask(i,j,k)=1;
         end
      end
   end
end
 isosurface(mask,0.9)
```

Stress and rest 3D images are compared and possible differences in voxels are calculated using MatLab image processing analysis. Thus, quantification and analysis of differences in 3D stress/rest images is permitted. As a result, the location of perfusion defects as well as the myocardium defect volume can be both identified precisely. This results in the quantization of the possible pathogenesis.

Results and Discussion

Two data sets of slices (stress/rest) were used in order to calculate the index ratio of the Volume of Interest (VOI) at rest and at stress. In cases of a healthy well-functioned myocardium, this ratio fluctuates between 0.950 and 1.1. In cases of a reversible ischemia, the VOI ratio becomes 1.15 – 1.5, whereas in cases of irreversible ischemia or other myocardial disorders, the ratio varies between 1.5 and 1.95.

3D image irregularities can provide visual and quantitative evaluation of myocardial perfusion. Furthermore, possible differences in voxels between stress and rest images are calculated.

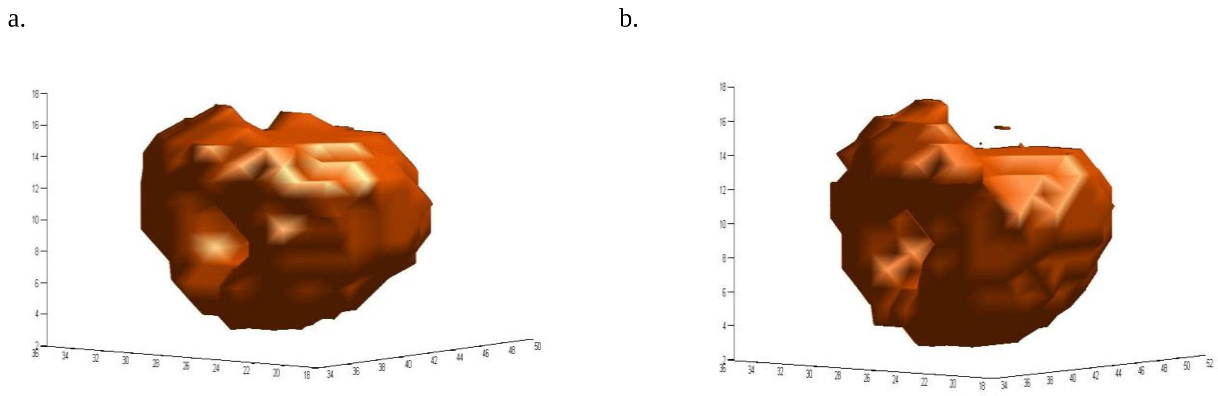

Figure 6: 3D respresentation of the Volume of Interest at rest (a) and at stress (b) of the same patient as in figures 4 and 5. It is obvious that the total volume is decreased at stress phase due to the general pathogenic condition. Therefore there is a defect of radionuclide perfusion when compared to the myocardium perfusion at rest.

VOI indices permit quantification and analysis of the differences between the 3D data obtained at stress and at rest. Thus, objective interpersonal comparison and objective assessment of the left ventricle deformation is enabled.

Further significant improvement in image quality will increase confidence in image interpretation [7-8].The development of algorithms for the analysis of myocardial images may allow better evaluation of small and non transmural myocardial defects. Our future work may focus on detecting precisely the voxels with no intensity in order to locate precisely the regions of the myocardium where there is no perfusion.

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