A NEW METHOD FOR SPECT MYOCARDIAL IMAGE SEGMENTATION BASED ON LEFT VENTRICULAR SPATIAL INFORMATION

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Abstract: This work presents a new method to perform automatic myocardial perfusion images segmentation. Myocardial perfusion scintigraphic images can be obtained through a gamma camera employing the SPECT technique. The SPECT technique is used to produce tomographic images of the radiotracer distribution inside the human body. As the acquired image in the myocardial scintigraphy present extracardiac areas with considerable radiotracer uptake, it is quite difficult to apply conventional segmentation techniques to enhance ventricle detection. This new approach to segment left ventricle images uses the expected heart location knowledge. So, curves derived from the pixels maximum values (PMV) of three orthogonal planes, transverse, coronal and saggital were used to define a rectangular area where the majority of the pixels belongs to the left ventricle. At first, transverse slices were used to delimit a range that contains all the left ventricle pixels, excluding the pixels above and below the heart. Finally, coronal and saggital slices were used to define ranges in the transverse slices that contain almost exclusively left ventricle pixels, forming in this way a rectangular area. We tested our algorithms in images from http://lad.dsc.ufcg.edu.br/spect a database formed by 103 normal myocardial perfusion exams, and the results were quite satisfactory.

Introduction

The present work refers to the development of algorithms to implement automatic left ventricular (LV) segmentation using a new method based on spatial information of the left ventricle. Scintigraphic myocardial images can be obtained using a gamma camera, employing the SPECT (Single Photon Emission Computed Tomography) technique [1].

The simplest form to isolate a region from a structure (segmentation) is thresholding. If the heart is the region with the greater radiotracer uptake in an image (structure), setting to zero the pixels below a certain fraction of the image's maximal pixel value will reduce or even eliminate extracardiac areas. Unfortunately, in myocardial perfusion images, hepatic activity may be well above that of the heart and pulmonary, splenic, and intestinal uptake is often of concern. In addition to this, the relatively poor image resolution can cause the effect that organs in close proximity to each other may appear connected.

More sophisticated approaches to segmentation have been devised that use adaptive thresholding or knowledge of the expected location, size, and shape of the heart [2]. In gated SPECT studies, isolation of the LV cavity or myocardium can also be performed identifying and clustering pixels whose count value change the most during the cardiac cycle, based on the assumption that count variations are a consequence of motion of activity-containing structures [2].

Once segmentation has identified and isolated the heart in the structure volume, heart edges, or boundaries are generally determined using some algorithm of edge detection. Edge detection may include thresholding [3], Gaussian fitting of count profiles across the myocardium [4], moment analysis of count profiles across the myocardium [5], gradient analysis of the count distribution in the myocardium [6], or gradient analysis of the LV cavity [7]. Gradient analysis typically identifies the LV epicardial and/or endocardial surfaces as the local minima and maxima collections of the count distribution across the left ventricle, although this approach is quite sensitive to noise and may require the combined use of smoothing techniques [7]. Another approach, applicable to perfusion SPECT imaging, starts by extracting the maximal count or midmyocardial surface and then estimates the endocardium and epicardium location by assuming a fixed myocardial thickness [8].

Our new approach to segment left ventricle images uses the expected heart location knowledge. So, we created curves derived from the pixels maximum values (PMV) of transverse, coronal and saggital planes to define a rectangular area where the majority of the pixels belongs to the left ventricle.

The objective was to find these rectangular areas in transverse slices, formed almost exclusively by left ventricle pixels. So, we hope to improve LV segmentation techniques and minimize processing time.

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Materials and Methods

In This work we collected images acquired by a tomographic gamma camera, installed in a specialized nuclear medicine service. These images are obtained in two phases, resting and stress phase. The material used was: ^{99m}Tc labeled myocardial perfusion tracer, ^{99m}Tc-sestamibi (Cardiolite™, Du Pont Pharmaceuticals, North Billerica, MA), and the data was acquired using a 20 seconds per projection rate, performing a total of 64 projections during a 180º rotation. The doses used in the studies were 555 Mega Becquerel (MBq) and 1110 MBq, for the resting and stress phases, respectively. The electrocardiography data was obtained during the exercise stress testing, or pharmacological stress testing for those patients whose exercise test was not indicated. The heart images are obtained after a post-injection interval of one hour for the resting and pharmacological stress phases, and thirty minutes for the exercise phase.

The radiotracer employed to label the myocardium distributes in extra cardiac areas. Figure 1 illustrates the labeled organs after radiotracer administration.

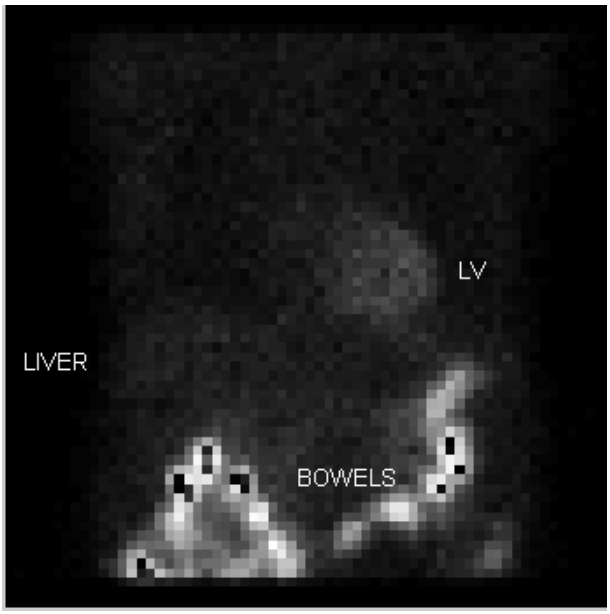

Figure 1: The LV and extra cardiac areas.

Image segmentation process consists of the subdivision of an image in different areas. Segmentation is the main stage for an automated analysis of the image. With the segmentation technique we can extract objects and other entities used for subsequent image processing, such as classification, description, count, recognition, among others.

Image segmentation can be approached from two different perspectives. The perspective that assigns pixels to particular objects or regions and other that attempts only to locate the boundaries that exist between regions. These perspectives are called respectively *region approach* and *boundary approach.*

The selection of one of these approaches or a combination of both techniques to perform the image segmentation depends strongly on the data type used and the application area. As the acquired image in the myocardial scintigraphy present extra cardiac areas with considerable radiotracer uptake, (figure 1), with even greater uptake when compared with the left ventricle, it is quite difficult to apply conventional segmentation techniques to enhance ventricle detection. Therefore, to perform automatic myocardial segmentation we propose the following methodology based on LV spatial information:

- Application of the inverse Radon transform [9];
- Determination of the Pixel's Maximum Values (PMV) in kilo counts per second (Kct/s) of each transverse slice;
- Curve fitting of the PMV versus transverse slices numbers;
- Use the PMV curve to determine the transverses slices that contain the left ventricle pixels;
- Compute the coronal and saggital orientation based on the transverse slices detected by PMV curves cited above;
- Curve fitting of the PVM now related to coronal and saggital slices;
- Use the coronal and saggital information to delimit a minimal rectangular area inside the transverse slices whose majority of the pixels belongs to the left ventricle.

We used the filtered backprojection algorithm to perform the inverse Radon transform, equation 1, which is commonly used in tomography applications. This transform inverts the Radon transform, equation 2, and can therefore be used to reconstruct images from projection data. So, we use equation 1 to obtain transverse slices of patient's thorax. Some of the transverse slices had in their majority, LV's pixels. So, we fit a curve (figure 2) derived from the pixels maximum values (PMV).

$$R^{-1}(r,\alpha)[f(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(r - x\cos\alpha - y\sin\alpha)dxdy \quad (1)$$

$$R(p,\tau)[f(x,y)] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta[y - (\tau + px)]dydx \quad (2)$$

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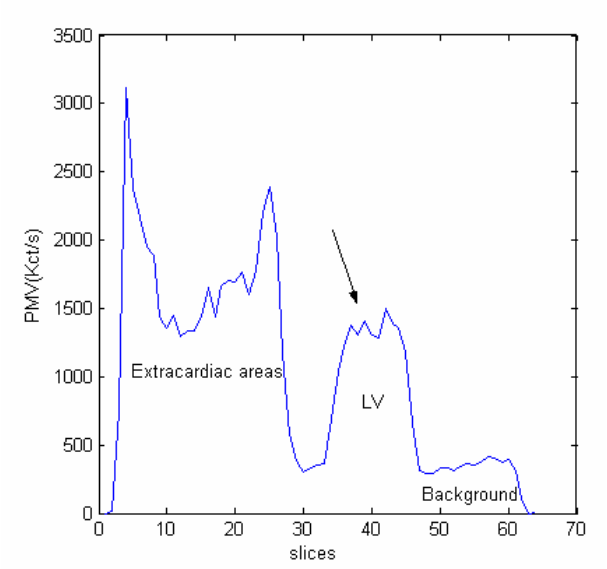

Figure 2: Transverse slices x PMV (Kct/s).

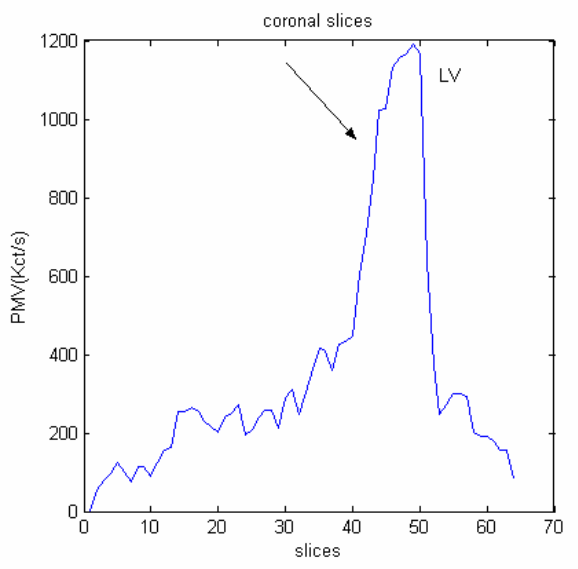

Figure 3: Coronal slices x PMV (Kct/s).

Figure 2, shows a curve with three distinct segments: LV, extracardiac areas and background. We implemented an algorithm to detect the range where could be the LV pixels. The algorithm is based on the activity variations within the background, LV and extracardiac areas, so, we established limits in percent terms of activities variation where can be detected the slices related to the extracardiac areas, left ventricle and background. Observing figure 2, we can see that extracardiac areas are from 2nd to 30th slices, the LV from the 33rd to 48th slices and background from the 49th to 64th slices.

After we found these transverse slices we used saggital and coronal orientation to fit curves derived from the PMV related to the respective orientation. In figures 3 and 4 one can see that LV pixels are between the ranges appointed by PMV curve. We use similar criteria to detect the slice range where could be LV pixels derived from the coronal and saggital orientation. Thus, the coronal slices generated a curve where the LV pixels are between the 40th and 52th slices (figure 3). The saggital slices generated a curve where the LV pixels are between the 40th and 57th slices (figure 4).

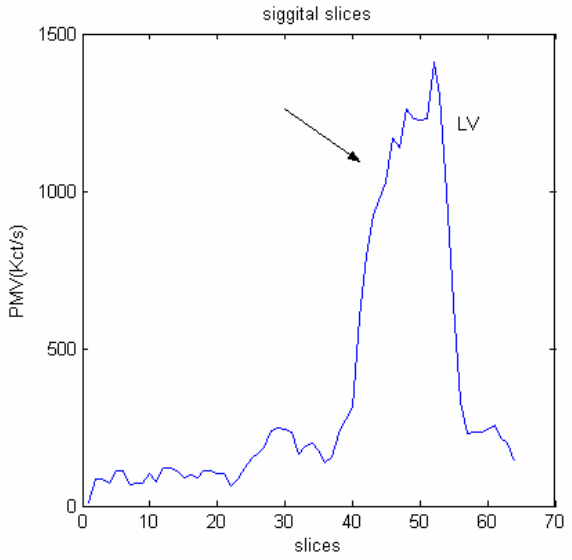

Figure 4: Saggital slices x PMV (Kct/s).

So, our algorithm detects the ranges where we can define a minimal rectangular area inside the transverse slices, whose majority of the pixels belongs to the LV. At first, transverse slices were used to delimit a range that contains all the left ventricle pixels, excluding the pixels above and below the heart's location. Finally, coronal and saggital slices were used to define ranges in the transverse slices that contain almost exclusively left ventricle pixels, forming in this way a rectangular area. We tested our algorithm using images from a database of 103 normal scintigraphic exams that we have created whose URL is: http://lad.dsc.ufcg.edu.br/spect, and for the majority of cases we obtained satisfactory results.

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Results

The technique described above was applied in a group of 103 patients whose scintigraphic exams were normal and the results were quite satisfactory. Figure 5 below illustrates one of these results. We observed just 2 cases (1.94%) where the LV wasn't appropriately classified, maybe due to severe patient motion.

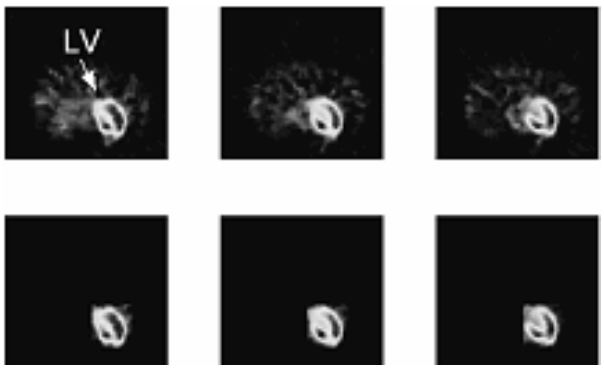

Figure 5: Top, transverse slices before segmentation. Botton, transverse slices after segmentation.

Note that the LV was approprieted classified in a rectangular area (figure 5) and the extracardiac activity were completely excluded from the images.

Discussion

We used the segmentation technique described above in a group of 103 patients with normal result in the myocardial scintigraphy exam. In this group, curves fitting of the PMV of the traverse sections were used to determine the slices that contain the left ventricle pixels. The PMV variations show the heart spatial location and we take these variations into account to find the left ventricle pixels.

The new methodology of myocardial perfusion images segmentation demonstrated to be efficient enough to improve the left ventricle detection, therefore it is possible to exclude extracardiac regions of considerable radiotracer uptake without operator aid. After the application of the technique described above we can make the use of simple segmentation techniques, as for instance, thresholding and edge detection to complete LV cavity classification.

To assure the quality of our results, we compared our automatic methodology with the semi-automatic approach used by SIEMENS image processing software, the ICON version 7.1, and our technique yielded quite encouraging results.

Conclusions

The segmentation technique presented in this work yields satisfactory results. The LV was segmented in an automatic way, using curves generated by PMV to determine the pixels that belong to the left ventricle.

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