

Effect of energy window width on the contrast and SNR of diagnosis of defects in different regions of myocardial phantom

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Abstract

Among non-invasive methods for the evaluation of ischemic cardiac disease, myocardial perfusion imaging using SPECT technique is firmly accepted; it allows obtaining quantifiable and useful information for the management and follow-up of patients with coronary artery disease. On the other hand, in SPECT study, window width of energy is considered as one of the most important physical factor affecting the image quality. Thus, the effects of window widths of energy 15%, 20% and 25% on the SPECT images of defects in different region of myocardial phantom were investigated. Herein, rectangular defects with the same thickness were inserted on the anterior, septal, inferoposterior and lateral regions of myocardial phantom. Myocardial perfusion study was performed with ^{99m}Tc . Raw data was reconstructed by filter backprojection method with Butterworth filter. Then, results of implementation of different energy windows on the contrast and signal to noise ratio of defects in transverse views of phantom images have been studied. Our measurements show that values of signal to noise and contrast is depend on the defect location and type of orbit. Results demonstrate that, using a 360° orbit and window width energy 20% showing better contrast and SNR for defects located in the inferoposterior defect than a 180° orbit.

Key Words: SPECT; myocardial phantom, energy window

I. INTRODUCTION

In the early 1970s, cardiology moved into the era of noninvasive nuclear assessment of myocardial perfusion and left ventricular function with the introduction of nuclear medicine imaging with potassium-43 and gated blood pool imaging [1]. Single photon emission computed tomography (SPECT) has become an important diagnostic tool in cardiovascular nuclear medicine. Currently, myocardial perfusion imaging [2, 3], particularly SPECT, is the most widely employed noninvasive method used for measuring the assessment of myocardium at risk, infarct size and treatment efficacy in acute myocardial infarction [4]. This technique has been also shown to provide useful

information on the metabolic and physiologic functions of organs through the reconstructed images of radiopharmaceutical uptake distributions [5].

In the SPECT technique, detector head (or heads) rotates around the cumulated activity in the patient body at small angle increments for collection of data over 180° or 360° . Although 180° data collection is commonly used (particularly in cardiac studies), 360° data acquisition is preferred by some investigators, because it minimizes the effects of attenuation and variation of resolution with depth. The recorded events are collected in the form of pulses at each angular position and normally stored in a 64×64 or 128×128 matrix in the computer for later reconstruction of the images of the planes of interest.

Several factors cause poor spatial resolution and image quality in the reconstructed nuclear medicine images such as scatter events in the patient body, collimators or scintillation crystals. Window width of energy is considered as one of the most important physical parameters for enhancement of image quality and scatter events suppression in SPECT images. The setting of energy window width allows the user to define rejection rate of scatter photons from all recorded photons in SPECT heads. So, narrower window width rejects more scatter photons and reduces the counts rate from the accumulated activity and vice versa. It seems possible to achieve more primary to scatter ratio and better image sensitivity simultaneously if the energy window width setting is considered carefully.

This work focuses on the evaluation of contrast and signal to noise ratio (SNR) of the acquired SPECT images of similar defects located in different regions -anterior, septal, inferoposterior and lateral- of myocardial phantom in the window widths of energy 15%, 20% and 25% by using a Tc-99m source at 140 keV. By obtained results, the effects of energy window width and type of camera head rotation on the contrast and SNR of defects images have been studied and the results have been interpreted. In the present study, it was evident that energy window width played a prominent effect on the image quality using the Tc-99m source and this effect is different for located defects on the different region of myocardial phantom.

II. MATERIALS AND METHODS

a. Myocardial Phantom

A cylindrical heart phantom consist of two co-axial tubes were made. The diameter and length of inner cylinder were 36 and 60mm, respectively. Dimension of outer cylinders were 60 and 74 mm which related to diameter and length of and outer tube. The space between the two tubes simulated the myocardial wall of the left ventricle and had a thickness of 12 mm and volume of 120 mL. For SPECT studies the myocardial wall of the left ventricle portion of the phantom was filled with 1 mCi ^{99m}Tc water solution. In clinical practice in this nuclear medicine center about 20 mCi of ^{99m}Tc is injected into patient from which about 1 mCi is taken by myocardium. To ensure uniform distribution, the tracer was mixed with water before filling. We fixed 4 rectangular defects of 20mm length, 20mm width and a thickness of 8mm, so that the normal vectors of the extended surface of the rectangular pieces were plumb to the phantom long-axis. These pieces were inserted at four regions in anterior, septal, inferoposterior and lateral regions on the inner wall of the myocardial wall of the left ventricle portion of the phantom. This region of the phantom was then filled with ^{99m}Tc water solution, and at ROR (21.0cm) the SPECT studies were performed.

b. Acquiring and Processing

The gamma camera used in this study was a dual head variable angle system, model ADAC EPIC Vertex. A low energy high-resolution collimator (LEHR) was used for imaging. Images were recorded over 180° from 45° right anterior oblique to 45° left posterior oblique. The 180° angular sampling particularly is optimal for cardiac SPECT due to the attenuation artifacts that result from reconstructing posterior projections. Matrix size 64×64 with an acquisition time of 25 seconds per projection and 32 projections in a step-and-shoot mode were used. This protocol is in accordance to the international recommendation for saving computer memory, decreasing the time of collecting counts and obtaining the best quality images. Moreover, the time of investigation the patient was limited and very short, 15 min; throughout this period the patient should be fixed without any motion to eliminate image artifacts. Then, the raw data was reconstructed by filter backprojection method using Butterworth filter. The Butterworth filter is one of the most popular low pass filters used in SPECT imaging especially in nuclear cardiology [6]. It is because the ability to change its shape through the cut-off frequency and other parameter which also better adaption of the filter function to the frequency characteristics of the projection data. Butterworth filter in spatial frequency domain (f) has two parameters (equation (1)); the cut-off frequency (f_n), and the order of the filter (n) [6].

$$B(f, f_n, n) = \left[\frac{1}{1 + (f / f_n)^{2n}} \right]$$

We have used the value of 0.35 and 5 for cut-off frequency and order, respectively, that frequency used in this nuclear medicine center.

We used window widths of energy 15%, 20% and 25% in three steps of experiments. In the final step, matrix size 128×128 and window width 20% over 360° orbits were used with the same parameters in previous acquisition. Indeed, with increasing of window width energy, recorded events in the SPECT head have been increased. But, as shown in Figure 1, these events also include corrupted events produced by Compton interactions of gamma rays with scintillation crystal of SPECT heads, collimators or patient body.

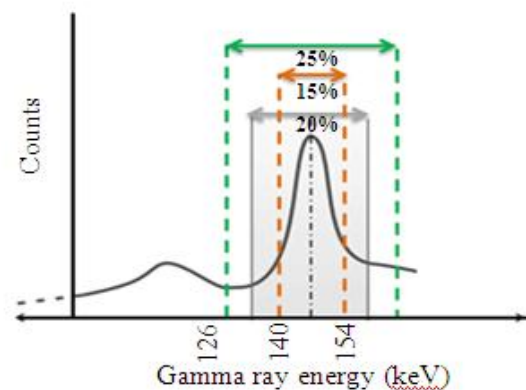


Figure 1. Representation of the relationship between the energy window width 15%, 20% and 25% of energy spectrum of Tc-99m and the relative number of counts

For each slice selected, segmentation was performed to define the normal myocardium and defects regions. Four squares regions of interest (ROIs), as illustrated in Figure 2-a, were drawn to calculate the mean numbers of counts corresponding to each defect (R_D). And so, four block arcs ROIs, as shown in Figure 2-b, were used to estimate mean numbers of counts in normal myocardium region (R_M). With these results, contrast of each defect was estimated by:

$$\text{Contrast} = \left[\frac{R_D - R_M}{R_D + R_M} \right]$$

We draw some line profiles by software of SPECT workstation through the defect locations from the normal myocardium to defect regions and further in the transverse view of our phantom images. To obtain SNR of defects diagnosis, difference of maximum count in normal myocardium ($N_{M(\max)}$) from minimum count in the defect region ($N_{D(\min)}$) was divided to minimum count in background (heart hole region ($N_{H(\min)}$)) as follow:

$$SNR = \left[\frac{N_{M(max)} - N_{D(min)}}{N_{H(min)}} \right]$$

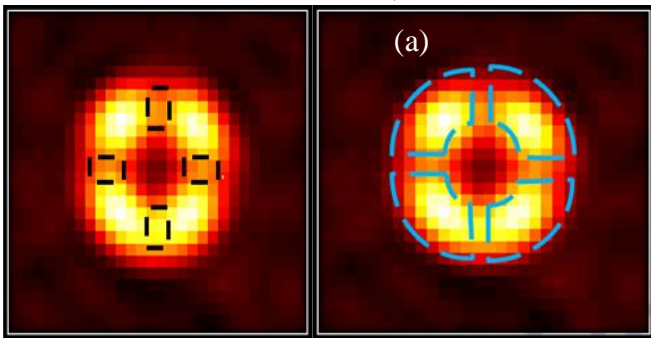


Figure 2. Demonstration of myocardium segmentation results; four square ROIs corresponding to lesions (a) and four block arcs corresponding to myocardium regions

III. RESULTS

The results of the contrast of defects diagnosis has been shown in Figure 3. Diagrams related to 180° orbit demonstrate that the best result is related to the anterior defect (Figure 3-a, b and c). And then, images of septal and lateral defects have acceptable values for the contrast, respectively.

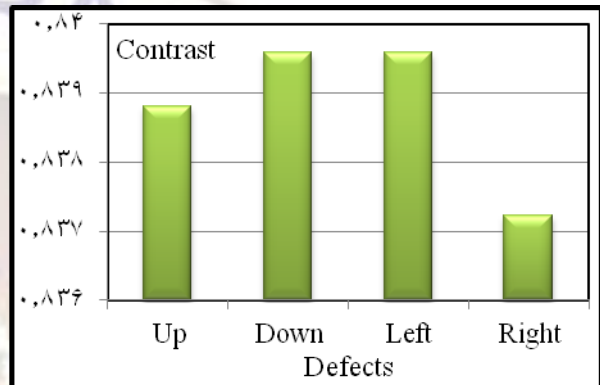
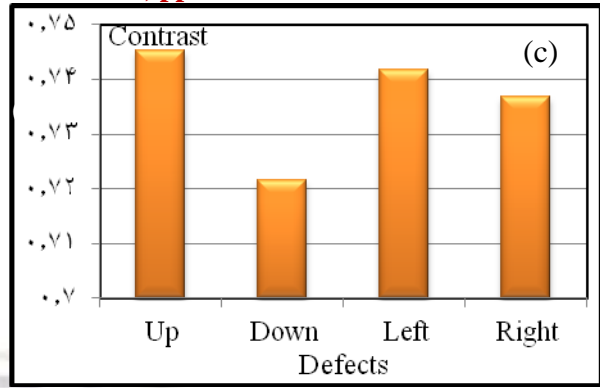
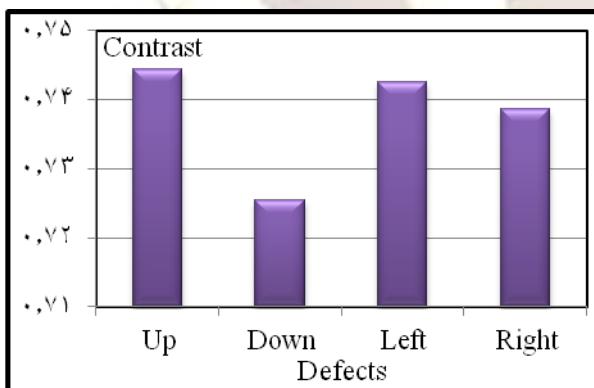
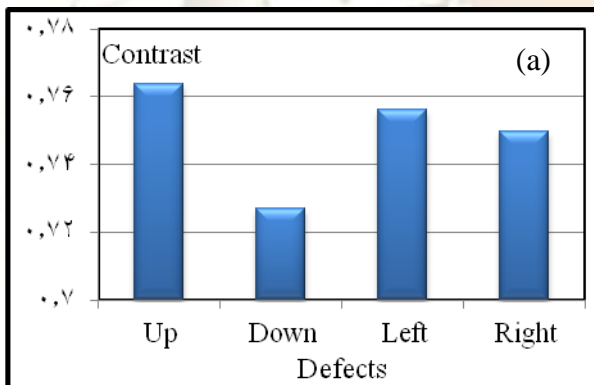


Figure3. Diagram of contrast of anterior (up), septal (left), inferoposterior (down) and lateral (right) defects for window width energy 20% (a), 25% (b) and 15% (c) in acquisition orbit 180° and in acquisition orbit 360° (d)



Diagrams show that the worst results belong to the inferoposterior defect which has the lowest value in contrast diagrams in all energy windows by using a 180° orbit.

But the obtained results by using a 360° orbit (Figure 3-d) is somewhat different than 180° orbit. The results show that the values of contrast of the four defects are very close to each other. Furthermore, the calculated contrast in this situation is much more than the formers.

A comparison between the obtained results by using a 180° orbit show that the best contrast is related to the energy window of 20%. Results of 15% and 25% energy windows are very close to each other, but the results of 25% energy window are slightly better than another.

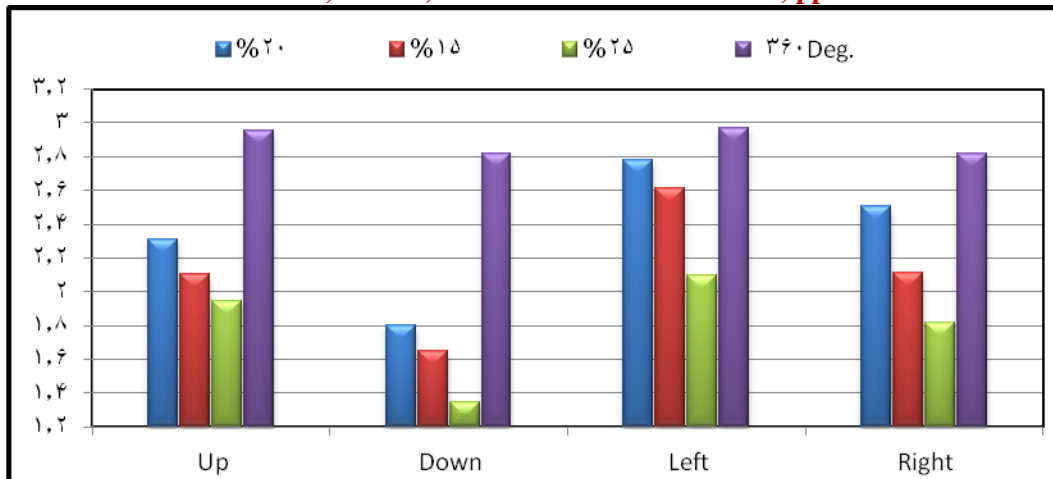


Figure 4. Diagram of SNR of anterior (up), septal (left), inferoposterior (down) and lateral (right) defects for window width 15% ■, 20% ■ and 25% ■ in acquisition orbit 180° and in acquisition orbit 360° ■

The SNR results of four defects diagnosis in different window width energy could be seen in Figure 4. Diagrams show that the SNR of the image of anterior defect could produce the best result and the worst results belong to the inferoposterior defect. The behavior of results obtained by different energy window by using a 180° orbit in this figure looks similar.

On the other hand, the results as shown in Figure 4 demonstrate that better results are produced by using a 360° orbit than 180° in all conditions. A comparison between the obtained results by turning over 180° orbit shows that energy window 20% will produce the best results. And then, the best results belong to the energy window of 15%.

IV. DISCUSSION

The obtained results by using a 180° orbit show that the best SNR and contrast of defects diagnosis are related to located defects in anterior, septal and lateral regions of myocardial phantom, respectively. While in the turning over 360° orbit, the results of different defects are almost similar to each other. So, the weaker results obtained by using a 180° orbit for inferoposterior defect can be attributed to the type of rotation of the camera heads around the myocardial phantom, which is in accordance to the international protocol for the clinical myocardial SPECT.

The results show that although a narrower window rejects more scatter photons but also reduces the counts from the myocardial phantom. This increases the resolution and image quality but decreases the sensitivity of the system. Thus, count rate per pixel decreases, and so the produced noise due to the Poisson distribution of counts caused by the radioactivity decay increases.

On the other hand, with increasing of the energy window width, although acceptance capacity of scattered events or system sensitivity increase,

but the existence of more corrupt events in recorded events cause image blurring and decrease the spatial resolution of reconstructed images. So the energy window of 20% balances between the suppression of the corrupt events and image sensitivity in comparison with energy window of 15 and 25 percent.

V. CONCLUSION

Contrast and SNR of diagnosis of the defects located in the different location of wall of the heart, especially in the inferoposterior region, is affected significantly by the energy window width and type of acquisition orbit. The results show the advantage of the energy window of 20% windows than energy windows 15 and 25 percent. The results show that the contrast and SNR of located defect at the inferoposterior region of the myocardial phantom are much worse than other defects, which can be related to the manner of the camera heads rotation around the myocardial phantom in the cardiac imaging protocol type. Indeed, produced results for the inferoposterior defect is worse than other peripheral defects, because this defect is less than the others under direct observation of camera heads. Therefore, in the cases of clinical study in myocardial SPECT, diagnosis of located defect in this region and its severity is more difficult than located defects in the lateral, septal and anterior regions.

Although a full rotation of the camera by using a 360° orbit could improve the contrast and SNR of diagnosis of the four defects, especially inferoposterior defect, but in this situation time of data acquisition is two times needed time for recommended protocol of heart SPECT. Thus, using of full rotation of SPECT heads in the clinical study is troubling for the patients and also reduces the useful lifetime of the device. Therefore, using a 360° orbit is only recommended if accurate

diagnosis of inferoposterior defects is needed for patients with coronary artery disease.

References:

- [1] Russell RR and Zaret BL (2006) "Nuclear Cardiology: Present and Future" *Probl Cardiol*, 31:557-629.
- [2] Botvinick E (2001) Ed. *Nuclear Medicine Self Study Program III—Nuclear Cardiology Topic 6-Myocardial Perfusion Scintigraphy—Clinical Aspects*. Reston, MD: Society Nuclear Medicine.
- [3] Gullberg GT and Zeng GL, (2005)"Cardiac Single-Photon Emission-Computed Tomography Using Combined Cone-Beam/Fan-Beam Collimation", *IEEE Trans. on Nucl. Sci.*, 52: 1.
- [4] McKusick KA, Holman BL, Jones AG, Davison A, Rigo P, Guemes L, Vosberg AH and Moretti J (1986) "Comparison of three Tc-99misonitriles for detection of ischemic heart disease in humans" *J Nucl Med*, 27, 878-882.
- [5] Liangy Z, Ye J, Cheng J, Li J and Harrington D (1998) "Quantitative cardiac SPECT in three dimensions: validation by experimental phantom studies" *Phys Med Biol*, 43, 905–920.
- [6] Germano G (2001) "Technical Aspects of Myocardial SPECT Imaging" *the J Nucl Med*, 42: 10: 1499-1507.