

**CARDIOLOGY, Review Article****Gated Myocardial Perfusion SPECT Imaging****Ziada, G.\* Khalil, M.\*\* and Nasr, H.\*\*\***

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Nuclear medicine has well established role in the diagnosis of many cardiovascular disorders. This is performed by several diagnostic procedures that are able to identify the perfusion and functional status of the heart. The clinical examinations involved are planar and tomographic gated blood pool, first pass, myocardial perfusion single photon emission computed tomography (SPECT) performed with or without electrocardiographic (ECG) gating. This range of diagnostic tools has their well defined use in answering many questions raised by the referring physicians. A detailed description of these examinations and their clinical as well as technical background are outside the focus of this review. However, the later diagnostic test has become a standard in patients undergoing myocardial perfusion imaging since it synergist the interpretation process by providing valuable information about the heart function. Thus, the main objective of this review is to give the reader a comprehensive overview about the current status of gated myocardial perfusion tomographic imaging and its methodological aspects with some emphasis placed on different computational methods used in clinical practice.

**Introduction**

Radionuclide myocardial perfusion using single photon emission computed tomography (SPECT) is a noninvasive technique used to detect and diagnose patients with known or suspected coronary artery disease. The technique provides valuable information about coronary blood flow in addition to extent and severity of the diseased myocardium. In early days of nuclear medicine, most examinations were performed using planar gamma camera with a number of static images acquired at different viewing angles. During that time, Tl-201 was the radionuclide of choice due to its analogy to potassium kinetics. Planar imaging provides little information about the 3D nature of pathological lesions and thus unable to depict the spatial distributing of the perfusion defects. Additionally, the images acquired had poor spatial contrast. However, the introduction of tomographic examinations using single photon tomographic imaging into clinical practice has resulted in an improvement of many nuclear procedures especially those concerning cardiac examinations. Myocardial SPECT has led to improved contrast resolution and lesion detectability.

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Further progress has been implemented by using multiple detector systems with enhancement of count sensitivity and reduction of imaging time.

The last decade has witnessed a tremendous change in the practice of nuclear cardiology. Technologic advances resulted in a number of dedicated gamma cameras designed with characteristics that specifically suit cardiac patients. The successful results obtained from prototypes have motivated the introduction of these systems into the market. Some of these systems are equipped with x-ray Computed Tomography (CT) that is able to provide an accurate attenuation correction and lesion localization. CT systems are also able to provide information about coronary angiography and when combined with perfusion images can result in substantial diagnostic information in one imaging session.

Another area of research being conducted and have been implemented in commercial software programs are the inclusion of resolution recovery in the reconstruction algorithms so that a significant reduction of image noise can be achieved. Applying these corrections to data acquired with less acquisitions time, and hence high noise levels, showed an adequate and comparable results to those acquired in longer acquisition times.

One more point is the development of semiconductor gamma camera dedicated for imaging cardiac patients. This commercial introduction of such systems came as a result of using a room temperature, high density, semiconductor materials such as Cadmium Telluride (CdTe) and Cadmium zinc telluride (CZT). Performance measurements yielded an improved spatial resolution, sensitivity, count rate performance, and energy resolution. For reviews on recent advances in SPECT and nuclear cardiac instrumentation, the reader is referred to [1,2,3].

One of the remarkable advances in nuclear cardiology has been the combined myocardial perfusion with ECG gating in one imaging session. This has made a tremendous influence on the amount of information that can be obtained from cardiac scintigraphy. This procedure enables the interpreting physicians to obtain additive diagnostic information regarding myocardial perfusion in combination with myocardial functional parameters. The later advantage permits one to depict regional myocardial wall motion, wall thickening in addition to measurement of end-diastolic volume (EDV), end-systolic volume (ESV) and hence calculation of LV ejection fraction (EF).

#### **Why gated SPECT is clinically useful?**

The rapid growth and diffusion of gated SPECT imaging was due to a number of advantages the technique has provided to the interpretation of myocardial perfusion images. One of these is the added diagnostic and prognostic values that have been proved by realizing its potential implications in patient management [4]. Various studies have reported the benefits and advantages that can be obtained from GSPECT imaging:

Gated myocardial perfusion SPECT imaging provides an improvement for myocardial perfusion imaging in increasing the diagnostic accuracy of detecting patients with coronary artery disease [5]. It enhances the detection of multivessel disease and permits the assessment of the hemodynamic significance of angiographically detected coronary stenotic lesions. Cardiac imaging as a gatekeeper to cardiac catheterization is encouraged in management of patients with chronic stable angina in order to minimize the rate of normal catheterizations and to enrich the angiographic population with a greater proportion of patients with significant, yet treatable disease [6]. Furthermore, the technique provides reliable

and reproducible measures of left ventricular functional parameters. These quantitative approaches decrease inter- and intra-observer variability and facilitate serial assessment of myocardial perfusion and function [7].

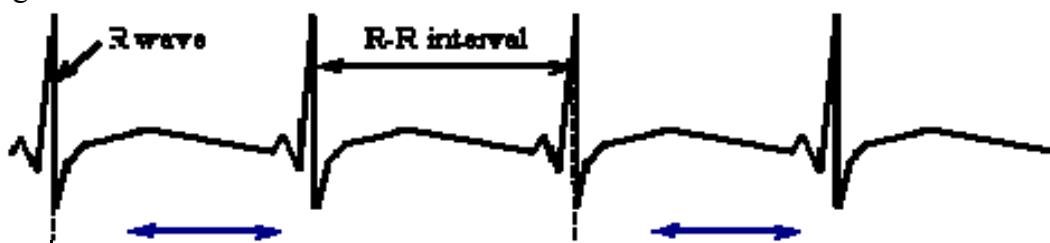
Risk stratification based on gated SPECT imaging has been shown to be a reliable and accurate tool in patient prognosis. In a study by Sharir et al. [8], post stress EF and the extent of stress induced ischemia provide complementary information in the prediction of risk of cardiac death. EF was the strongest predictor of mortality, whereas the perfusion summed difference score was the strongest predictor of Myocardial infarction [8]. The combined variables were more effective in risk stratification of patients than were the stress nuclear variables or post stress EF alone [9]. An interesting therapeutic application of GSEPECT imaging is the detection of response to therapy, revascularizations, and treatment outcome. Whenever moderate to severe ischemia is found by nuclear testing in patients with previous revascularization, consideration should be given to repeat catheterization [10]. Cost-effectiveness analyses further indicate a role for myocardial perfusion imaging in reducing the rate of revascularization in

patients with symptoms of stable angina, with no implications as to patient outcome [11].

## How Gated SPECT is performed?

### Acquisition

The conventional way of acquiring myocardial perfusion study is to take a multiple 2D images around the patient. A camera rotates around the patient for at least 180 degree, stopping at regular number of angular intervals. The angular interval is determined by the number of stops and the total acquisition arc. For each stop, the camera obtains a snap shot image of myocardial activity distribution. To obtain functional information, a 3 lead ECG-trigger is attached to the patient chest to input a QRS signal to the acquisition computer. The R-R interval is utilized to obtain a number of gates or intervals (i.e. 8 or 16) for each cardiac cycle, **figure (1)**. One gate represents a volumetric status during the periodic systolic-diastolic cycle. The study acquisition may be time, count, or trigger dependent. All are nearly equivalent as long as an adequate image statistics is achieved [12].



**Figure (1).** The R-R interval

While a single head gamma camera is technically able to image and acquire a simultaneous myocardial perfusion combined with ECG gating, the use of multi-detector system would be more

efficient in collecting better counts statistics in addition to a significant reduction of imaging time. This is of particular importance in busy nuclear cardiac units and influences significantly on scanner throughput. A short scanning time also helps to avoid patient motion and provides patient comfort. Acquisition parameters with

matrix size can be either of 64x64 or 128x128. The former is frequently used as it preserves large counts per pixel in a given patient study. Because myocardial perfusion SPECT can be performed on the same day or on a two separate days, gated SPECT can be applied on either case. However, in the same day protocol, gated SEPCT data are preferred to be with the study of the larger injected dose. This is to improve count sampling statistics and also important for reliable measure of functional indices. Low energy high resolution collimator is frequently used in the literature, however, general purpose collimator is a possible alternative since it improve the statistical quality of the scan.

### **Processing**

The raw data are received in the form of unsummed 8 or 16 gated bins for each projection angle. To obtain data regarding myocardial perfusion, the cardiac frames are summed together in a composite manner to reveal information as if they would have been acquired in a non-gated acquisition mode. Data reconstruction can be executed using analytic approaches such as Filtered back projection (FBP) or iterative reconstructions such as Maximum likelihood expectation maximization (ML-EM) or Ordered Subset- Expectation Maximization (OSEM). Low pass filtering such as Butterworth and Hanning filter are commonly used. Because the cut-off frequency is an important parameter that determine the final smoothness or sharpness of the images, it is not recommended to change the cut-off frequency on a blindly manner. The cut-off frequency can alter the interpretation results of myocardial perfusion as well as myocardial function. Thus, once the values has been set, taking into consideration factors that affect image signal-to-noise ratio, then it is not advised to change the cut-off values according to

individual preferences. Factors that influence signal to noise ratio are imaging time, injected dose, variation in patient sizes,, etc.

The selection of the cut-off frequency was found to influence the calculations of the left ventricular volumes as well as EF. This has been demonstrated by our group and others and will be discussed later.

Data reconstruction yield transverse cardiac slices for each time frame and image reorientation is performed in the three orthogonal planes across the myocardial axis to produce the standard horizontal, vertical and short axis slices. Image reconstruction for the unsummed or gated data produce a set of images for each cardiac cycle that shows the ventricle kinetics in that particular phase. Calculations of the LV function parameters are then carried out by use one of the commercially available quantitative methods

### **Gated SPECT Methods**

Many attempts based on several and different theoretical assumptions were given to calculate the left ventricular volumes and EF Gated SEPCT methods can generally be divided into three main categories: geometric based, count-based, or hybrid methods. In geometric based methods, the left ventricle is modeled as ellipsoidal, prolate spheroid, or spherical-cylindrical approach. In count based methods, the count change among and within cardiac frames throughout the cardiac systolic functions is utilized in the estimation process. Hybrid methods combine between both approaches and utilized in a number of commercialized software programs

### **Factors facilitated the introduction of GSPECT**

Thallium-201 was the common radionuclide in cardiac imaging and has been used for many years in assessing patients with

coronary artery diseases. However, the introduction of Tc-labelled compounds such as tetrofosmin and sestamibi has resulted in a higher injection dose, better counts statistics, and longer time is permitted before isotope injection and launching image acquisition. Gated SPECT imaging also requires a fast processing speed and high storage capacity. Further, owing to the fact that the R-R interval is divided into frames; data sampling regime requires adequate count sensitivity. The former has been tackled by using fast computer processors and memory chips. The later requirement has been solved by using a detection system of multiple detector heads, larger injected dose, or relatively prolonged acquisition time.

These features contributed in such a way that made GSPECT imaging a clinically feasible. Manufacturers nowadays are providing gamma cameras with two or more detectors showing better count sensitivity and reduced statistical uncertainty. The striking point was the development of fully automated algorithms able to reconstruct and calculate the LV function in less than a minute. We will present some of the methods proposed to evaluate the LV function along with their theoretical assumptions

### **Quantitative Gated SPECT (QGS) Method**

QGS was developed by Germano et al in 1995 [13]. The method is fully automated and works in 3D dimensional space to sample the myocardium using ellipsoidal model. The method uses fundamental image processing tools such as thresholding, binarization, and data clustering to segment and isolate the left ventricle from the nearby structures. Minimum volume was set to 50 ml to be as a threshold above which the algorithm searches the entire short axis

images. Because the activity distribution along a radial profile drawn normally on the myocardial wall is more likely to be asymmetric in shape, an asymmetric Gaussian function is employed to fit these profiles using pre-defined standard deviations. These SDs were calculated by phantom studies and was found to be 65% of the profile width. QGS uses the count density change among and within frames to calculate the myocardial thickening and thickness utilizing the law of the conservation of mass [14]. **Figure 2** shows a screenshot of QGS output display.

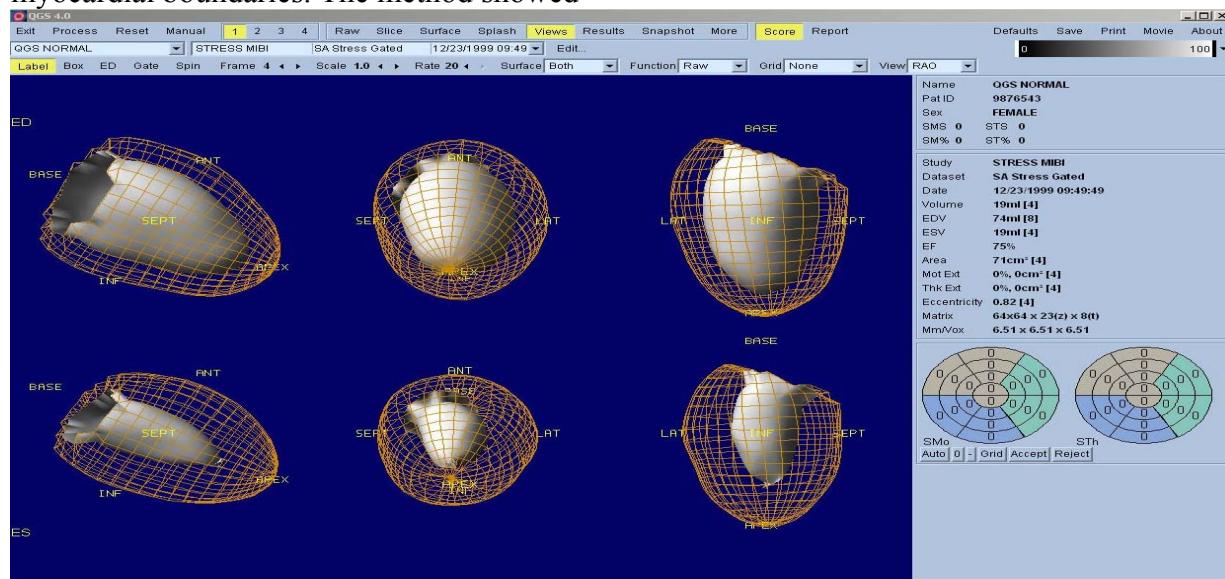
**Emory Cardiac Toolbox (ECTb) Method**  
Emory Cardiac Toolbox was reported in 1999 by Faber et al [15]. The method uses two geometric systems for sampling counts along the myocardium, **Figure (3)**. It employs cylindrical geometry to sample the mid and basal part of the myocardium but spherical one is used to sample the apical portion. ECTb method uses the partial volume effect to calculate the myocardial thickening using Fourier transform[16]. By assuming the myocardial thickness to be 10 mm at end-diastolic phase, the endocardial and epicardial offsets are then estimated for all the myocardial frames. **Figure 4** shows an end result of myocardial perfusion study processed by ECTb

### **4D-MSPECT**

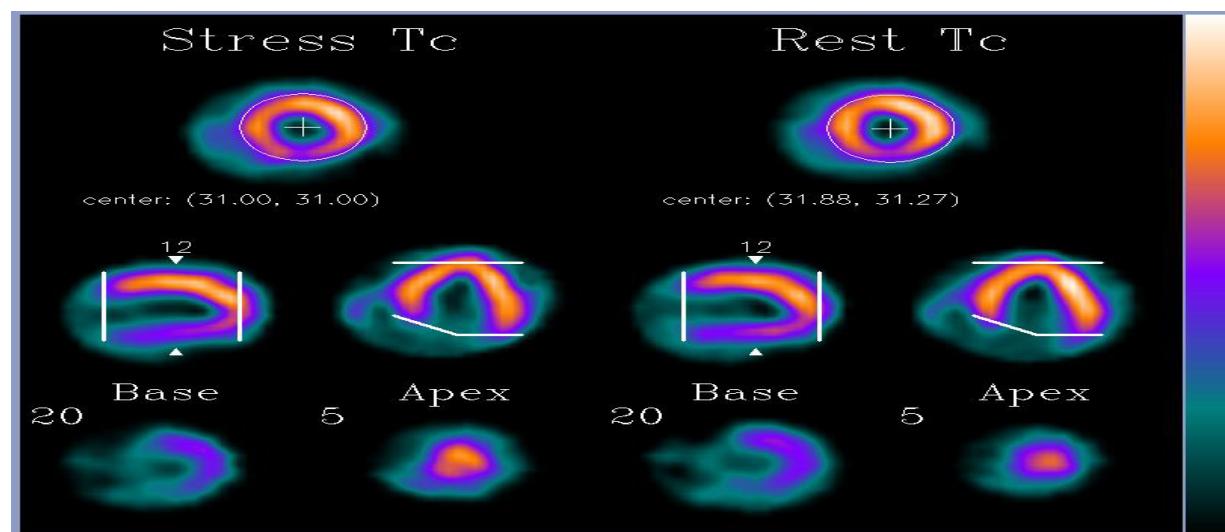
4D-MSPECT was developed by Ficaro et al (17) at the University of Michigan, USA. A semi-automated 4D-MSPECT software processes data on the basis of a 2-dimensional gradient image from which the initial estimates of the ventricle are made. A series of 1- and 2-dimensional weighted splines are used to refine the endocardial and epicardial surface estimates. The 4D-MSPECT model uses also a cylindric-spheric coordinate system. The cylindric coordinates are used to sample from the

basal wall to the distal wall and spherical coordinates are used to sample the apex (18). By using Gaussian functions, wall position and thickness are estimated. Like QGS and ECTb, 4D-MSPECT has the capability for manual processing when the automatic module fails to accurately delineate the myocardial boundaries. The method showed

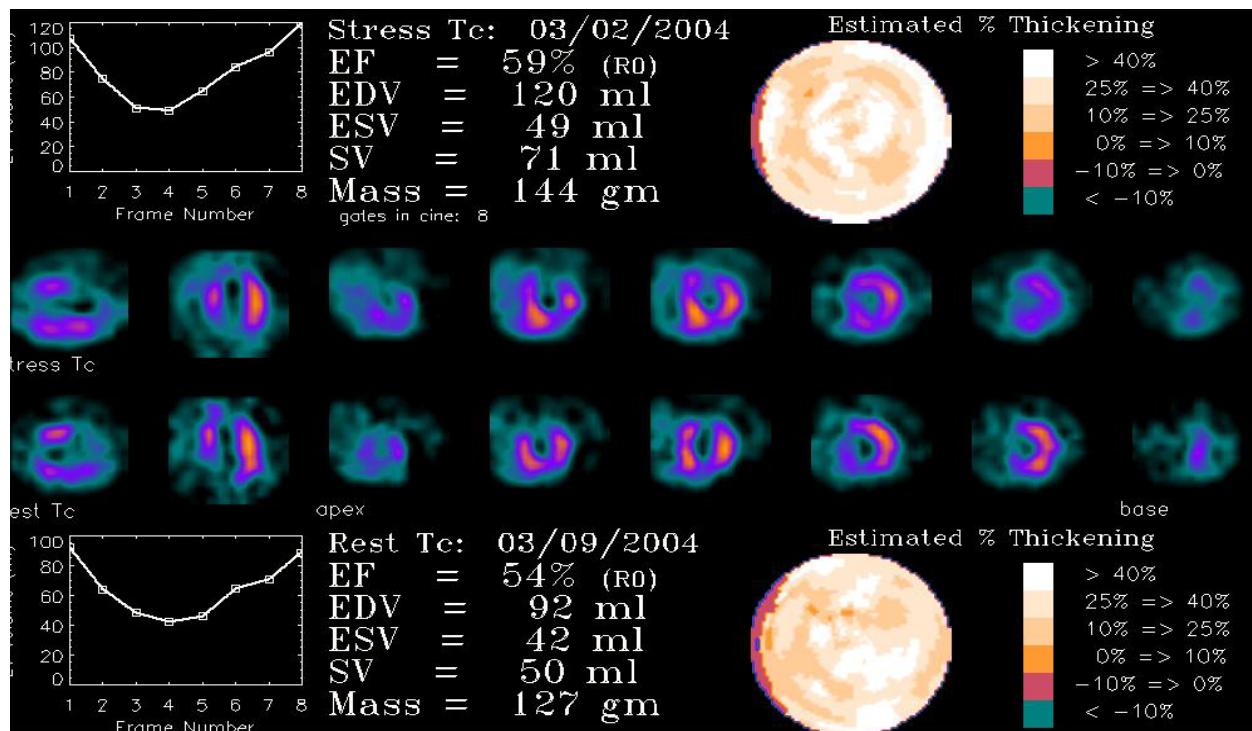
a good correlation with magnetic resonance imaging in the calculation of LV volumes and EF [19]. An example of 4D MSPECT is illustrated in **figure 5**



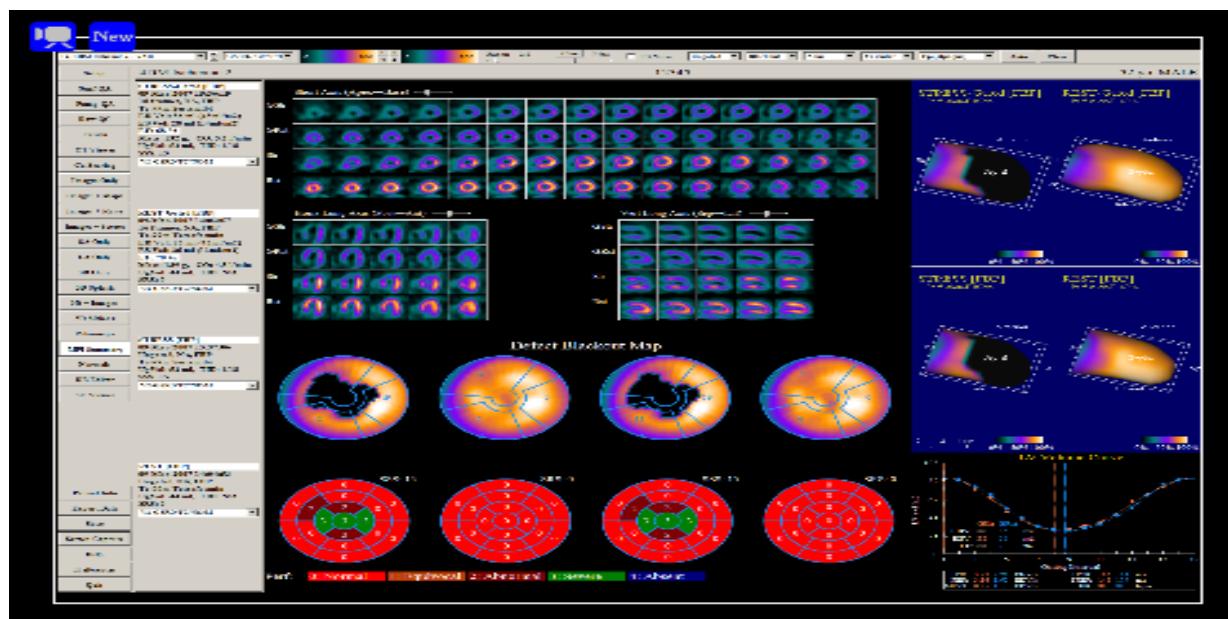
**Figure (2).** QGS output display. It shows a 3D dimensional grid for the LV from many directions (at ED and ES) and thus allows the reader to depict regional myocardial dysfunction



**Figure (3).** ECTb uses two geometric systems to define the whole myocardium. The mid and basal portion of the ventricle is modeled as cylindrical in shape while the apical portion is modeled as a sphere. The valve is defined as two intersecting planes to obtain the most basal slice of the ventricle.



**Figure 4.** ECTb output shows the left ventricles volumes and EF for a patient stress and rest scan. Samples short, horizontal, and vertical slices are displayed in addition to polar map of the LV wall thickness.



**Figure (5).** 4D-MSPECT shows the three orthogonal slices of myocardial perfusion study, together with the perfusion polar maps.

### **Layer of Maximum Count Method**

One of the limiting factors that constrain the performance of quantitative gated SPECT methods is data acquired for patients with small left ventricles. In an attempt to solve this problem, a relatively recent method was developed to correct for such an artifact [20,21]. This method is known as layer of maximum count method (LMC). It employs the prolate spheroidal transform to transform the spatial activity distribution of the left ventricle in the prolate spheroid system. Three angles are defined: A horizontal axis that lies along the transmural direction of the left ventricular wall, a circumferential angle that ranges from 0 to  $2\pi$ , and an azimuthal angle that ranges from 0 to  $\pi$  [21]. In each short-axis image, maximum count sampling is performed along the horizontal direction at fixed azimuthal and circumferential angles. A threshold of 50% is used to truncate the ellipsoid in order to fit the ventricular geometry. A tri-linear interpolation is used in data transformation. After data transformation, the left ventricle appears as an approximated plane surface, and the layer of the maximum counts (a surface area of maximum counts) is determined to calculate the enclosed volume,  $V_{max}$ . The  $V_{max}$  of the end diastole and end systole is calculated to compute the ejection fraction of the layer of maximum counts,  $EF_{max} = (ED_{max} - ES_{max})/ED_{max}$ .  $EF_{max}$  is then modified by the formula:

$EF = EF_{max} (1 + \text{constant})$  to compute the left ventricular ejection fraction. The constant in the formula is a multiplication of two constants, one related to the imaging system parameters like data acquisition, reconstruction algorithm, smoothing kernel etc., and the other is a ratio of the myocardial volume and the ventricular

Where  $f$  is the measured index of myocardial thickening. The method showed lower variability in measuring the regional

cavity. This latter constant was shown to be in a narrow physiological range [21]. By plotting the ejection fraction calculated by a reference method versus the  $EF_{max}$  while setting the intercept to zero, the regression slope ( $1 + \text{constant}$ ) could be obtained, which is also applicable for patients with small hearts. Khalil et al has recently evaluated the performance of LMC in patients with small left ventricles and showed a superior performance over other commercially available methods [22]. Moreover, the same group has recently assessed the method versus 2D echocardiography and demonstrated that the method can provide a reliable estimate of the EF with comparable variability with other well-validated methods [23]. Drawback of this method is its dependency on other reference and accurate methods in the calibration process.

### **Left Ventricular Global Thickening Ejection Fraction (LVGTF)**

This method depends on the detection of myocardial wall thickening during systolic contraction. The method relies on the partial volume effect, a phenomenon that makes the myocardial to waxes and wanes during heart contraction. In these circumstances, the pixel counts in end diastolic and end systolic images are used to quantify the myocardial thickening without edge detection or geometric measurements [24]. However, the method uses the systolic and diastolic counts in addition to geometric assumptions to derive a regional thickening fraction and hence to calculate the left ventricular ejection fraction using the formula:

$$LVEF = 1 - \left( \frac{1}{1+f} \right)^{3/2}$$

thickening throughout all left ventricular regions and also an excellent correlation with gated blood pool ( $r=0.91$ ,  $\text{slope}=0.97$ ). Furthermore, ejection fraction measurement

by this method is not dependent on the filter cut-off frequency used (24, 25). Due to many simplifying assumptions postulated by LVGTF method, it showed inferior results than other quantitative gated SPECT methods [26]

### **Factors affecting gated SPECT imaging**

The addition of ECG-gating to myocardial perfusion imaging added some variables to the conventional myocardial perfusion imaging. Therefore, once gated SPECT imaging has been introduced into the clinic many researchers and practitioners were interested to identify the sources of imaging errors and its consequences on the functional parameters. Several research articles were released discussing many factors that influence the quality of GSPECT imaging and the resulting functional indices. On the acquisition level, proper selection of the acquisition parameters in addition to adequate injection dose serve to provide a sufficient count sampling for image reconstruction. Patient preparation, instructions, and comfort are also required to minimize motion artifacts and thus able to reduce the likelihood of repeating the study or generating imaging artifacts. Patients with arrhythmia particularly those with atrial fibrillation undergo ECG disturbances and hence gated acquisition may fail in such group of patients. Not only the functional parameters are affected but also the perfusion ones. Sciagra et al found that the simultaneous acquisition of gated and nongated myocardial perfusion SPECT (a feature provided by some imaging systems) in patients with atrial fibrillation have a technical importance in removing errors that may come from the summation process [27]

### **Acquisition**

#### **Tl-201 versus Tc-99m based gated myocardial SPECT**

An important factor that is always concern the quality of scintigraphic images is the

number of counts collected. Because the noise in nuclear images is stochastic in nature, a large number of counts are recommended to reduce the statistical noise associated with radioactive decay. The emission rate of Tl-201 tracer is significantly lower than that of Tc-99m such that considerable differences can be seen in Tl-201 based images rather than those obtained from Tc-99m based tracers. The introduction of Tc-99m based tracers (Sestamibi and Tetrofosmin) has enhanced the quality of myocardial perfusion SPECT as well as the ECG-gated studies. Some investigators compared the functional parameters obtained by Tl-201 and Tc-99m gated SPECT. EF measurements obtained by Tc-99m sestamibi have shown better reproducibility (5.5%) than that by Tl-201 (10.3%) [28]. The low energy of Tl-201 produces a high amount of scatter in the acquired images, which decreases the certainty in edge identification. The low energy photons produce substantial scatter counts and hence Tl-201 studies are blurred with less sharpening.

The gated images are characterized by low count statistics which in turn may influence the performance of the quantitative algorithms in estimation task. However, when the acquired data are statistically adequate, a better confidence in outlining the boundaries is achieved. Count statistics are influenced by many factors such as injected dose, acquisition time, and time after injection, energy window (15% vs. 20%), system sensitivity, patient size, collimation, number of frames set to the cardiac cycle

The effect of background activity was studied and revealed a significant impact on volume and EF determination. Achtert et al reported that higher extracardiac activity may interfere with the delineation of the cardiac borders and thereby resulted in false determination of the volumes and EF [29], figure 6. Similarly, the injected dose and the

imaging time are important prerequisites for controlling the count levels in the gated study. Prolonged time after injection or low injected dose decreases the cardiac activity and hence might reduce the performance of myocardial contouring by the mathematical algorithm.

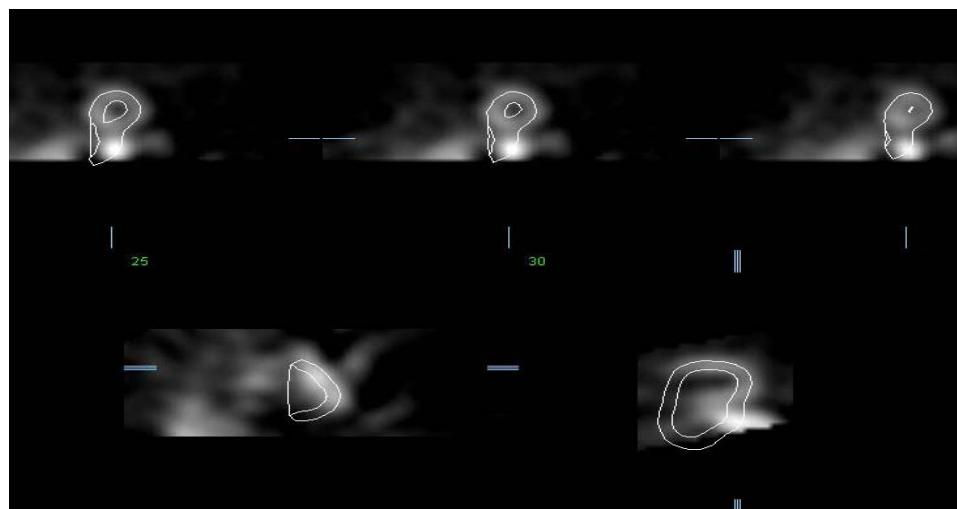
### **Image zooming**

Acquisition zoom is recommended during cardiac SPECT acquisition; however an optimal value may be from 1.3-1.6 to improve the magnification of the left ventricle. Too large zooming is not recommended to avoid truncation of the heart during image acquisition. Moreover, large zoom increases the number of pixels for an entire left ventricle, the matter which reduces the counts per pixel and results in higher noise level (30).

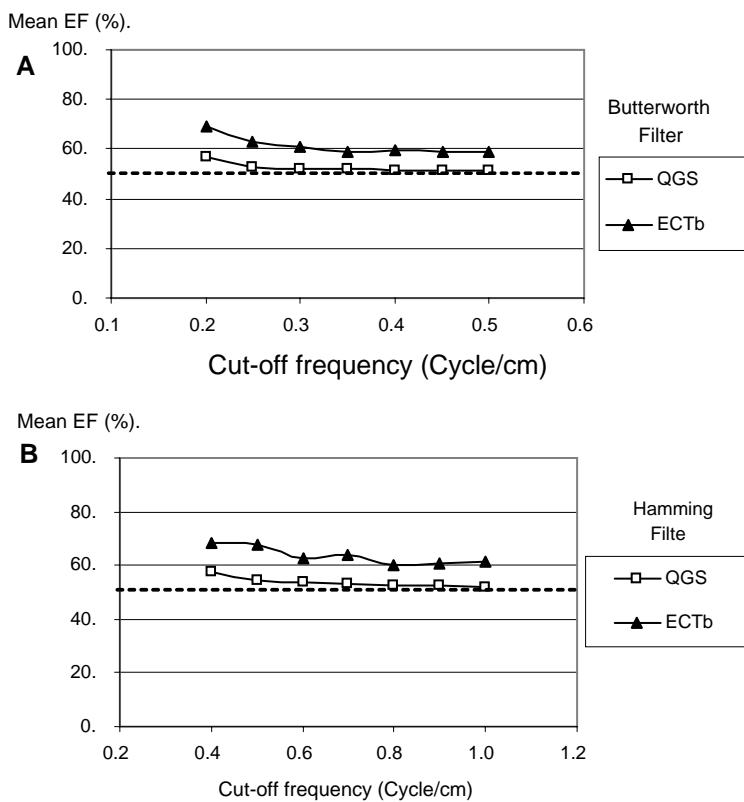
### **Collimators and type of rotation orbits**

Collimators play an important role in outlining the boundaries of different structures in the scintigraphic images. Also, the type of collimator determines the geometric sensitivity of the imaging system

along with spatial resolution. One study has compared the cardiac confocal collimator (which maintains the spatial resolution and provides a significant improvement in count sensitivity) and high resolution collimator for the calculation of the EF. Good correlation was found between both collimators; however the mean EF by Confocal collimator was significantly higher than that by high resolution collimator and Gated Blood Pool (GBP) ( $62\% \pm 10\%$  vs.  $54\% \pm 13\%$  vs.  $55.4\% \pm 12\%$ ). Two common types of orbits are routinely used in cardiac SEPCT imaging. These are circular "non-elliptical" or noncircular "elliptical" orbits. The former provides homogenous image resolution along all projections acquired, given that the heart-detector distance is approximately constant. On the other extreme, elliptical orbit minimizes the patient-detector distance to get the best possible resolution. However, this may impact adversely as resolution may differ considerably from projection to another producing image artifacts.



**Figure 6.** Inaccurate automatic contouring. The user should review the raw data as well as the reconstructed images for any possible failure in outlining the myocardial walls. [from Hermes installation documents, QGS version 4.0]



**Figure (7).** The response of ECTb and QGS to wide range of filter cut-off frequencies. The relatively higher EFs showed by both methods in comparison to gated blood pool might be attributed to inclusion of small LV in the patient population.

## Processing

### Reconstruction algorithms

FBP is the conventional reconstruction technique for SPECT images. The acceptable alternative to FBP is iterative reconstruction which could incorporate many physical degrading factors. Ordered subset expectation maximization algorithm was found to reveal better results than FBP when resolution recovery is included in reconstruction. Moreover, a substantial improvement was obtained when OSEM reconstruction was associated with Fourier filtering in gated myocardial SPECT using Tl-201 and Tc-99m as myocardial radiotracers [31,32]

### Filter cut-off frequency

The cut-off frequency in SEPCT reconstruction determines the degree of smoothing and hence the noise level in the

reconstructed images. We have evaluated QGS and ECTb using two reconstruction filters namely hamming and the commonly used Butterworth filter [33]. Both filters revealed similar results such that low cut-off values tend to reduce the LV volumes and overestimate the EF. However, boosting the filter cut-off appeared to stabilize the measurements where the volume nad EF curved showed a constant response a long a reasonable dynamic range that is used in clinical setting. [34]. Low cut-off frequencies were found to smooth the images to a degree that force the quantitative algorithm to underestimate the LV volumes and overestimating the ejection fraction. However, higher cut-off frequencies serve to improve the measurements but further increase may lead to introduction of noise

and confounding the computation task. Therefore, the optimal cut-off was investigated to be a range of values that lie between high and low frequencies, **Figure [7]**

### **Scatter and attenuation correction**

One of the physical factors that degrade SPECT images is the contribution of the scattered photons. It falsely represents the actual position of the emission site. Myocardial edges are therefore blurred and the ventricular cavity decreases in size. This might partially explain volumes underestimation noted by gated SPECT in comparison to other modalities<sup>34</sup>. By accounting for the scattered photons in the image acquisition, a recent report indicated an improvement in volumes determinations by QGS software in phantom and patient studies<sup>(34)</sup>.

A Preliminary study to assess the influence of attenuation correction on gated myocardial images in comparison to data not corrected has shown that the EF is underestimated, on average, by 2.9% due to the use of attenuation correction. However, the same study suggested that the functional estimates are still to be determined accurately without use of attenuation correction, as quantification algorithms were designed on data set obtained without attenuation correction and validation studies as well<sup>(35)</sup>.

## **Patients**

### **Small left ventricles**

Gated SPECT processing methods particularly those that depend on edge detection is very sensitive to the resolution of the myocardial walls. Poor resolution enlarges the myocardial thickness and thus minimizes the size of ventricular cavity. This problem is more obvious in patients with small hearts. For instance, in ECTb the algorithm assumes the wall thickness to be 1

cm at end-diastolic phase<sup>[15]</sup>. In systems with poor resolution, the reconstructed data may violate this assumption leading to false results.

QGS method depends on count profiles drawn normally on the myocardial walls, and the endocardial and epicardial offsets are determined by a given percentages of the profiles (65% of the Gaussian fitting profiles). Systems with lower resolution may underestimate the volumes and overestimate the EF. One study investigated that the left ventricular volume was underestimated by up to 13% as the SPECT spatial resolution deteriorates<sup>[36]</sup>. Software programs that depend on count density for estimating the ventricular volumes may be less affected by system resolution; however, the count statistics should be technically maintained.

### **Collimators**

The type of collimator determines the geometric sensitivity of the imaging system along with spatial resolution. One study has compared the cardiac confocal collimator (which maintains the spatial resolution and provides a significant improvement in count sensitivity) and high resolution collimator for the calculation of the EF. Good correlation was found between both collimators. However the mean EF by confocal collimator was significantly higher than that by high resolution collimator and Gated Blood Pool ( $62\% \pm 10\%$  vs.  $54\% \pm 13\%$  vs.  $55.4\% \pm 12\%$ )<sup>37</sup>

### **Perfusion defect**

In animal model, a trend toward volume overestimation was observed in presence of perfusion defects, however, the ventricular size of animals is questionable to represent that by human (38). Another study included patients with large myocardial infarction and calculated the volumes and EF by two algorithms (QGS and MultiDim) using Tl-

201 as a myocardial tracer revealed that QGS underestimated the EDV and EF but MultiDim overestimated the EDV and ESV. A tendency toward overestimating the ventricular volumes was observed with an increase in infarction size [39].

### Summary

Gated myocardial perfusion SPECT is a useful imaging technique for patients with known or suspected coronary artery disease. It provides additive diagnostic and prognostic information for the reading as well the referring physicians. However, the technicalities behind the procedure need proper adjustments and careful selection for the different acquisition and processing parameters. Ignoring or less recognition of these parameters could lead to error propagation and unreliable quantitative results. In this instance, It is not only the functional parameters that will be affected, but also the perfusion parameters can be confounded. Further studies are needed to assess the performance of hybrid imaging with regard to estimation of LV EF in absence and presence of CT attenuation correction.

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