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Estimation of stress left ventricular function from rest SPECT images using image processing

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Abstract: Myocardial infarction is the irreversible death of the heart due to lack of oxygen that occur when the blood supply is reduced or cutoff and isn't restored in an appropriate period of time. This study aim to assessment of ejection Fraction (EF) End Systolic Volume (ESV) and End Diastolic Volume (EDV) in myocardial perfusion imaging (SPECT) at the heart in stress status test from the heart at rest status test using a function written in the Interactive Data Language (IDL) software to normalize the image to range of count that classify the muscles of the heart to four classes normal, mild, moderate and severe, and recognize each part of the images as one of the classes. Same process applied to subsequent slice for the whole heart, and the number of pixels in each part counted to found a percentage of the heart classes. The result shows that we can estimate the EF with accuracy (90%±5%), ESV with accuracy (95%±3%) and EDV with accuracy (83%±5%) of the heart at stress status test from rest status test without stressing the patient.
Keywords: SPECT, Rest, Stress, myocardial perfusion

INTRODUCTION

Since the early 1990s, the use of stress myocardial perfusion (SPECT) has been continually growing, to play a central role in both the diagnosis and risk stratification of patients with established or suspected Coronary heart disease (CAD) [1].

The use of technetium 99m–labeled radiotracers and the addition of ECG gating to myocardial perfusion SPECT offered accurate and reproducible information in the assessment of both myocardial perfusion and ventricular function [2, 3]. Left ventricle (LV)functions (Ejection Fraction (EF), End Systolic Volume (ESV) and End Diastolic Volume(EDV), are measured using several noninvasive imaging techniques suchas 2- and 3-dimensional echocardiography, cardiac magnetic resonance (CMR) imaging, and different radionuclide methods such as planar multi-gated radionuclide angiography and gated myocardial perfusion single-photon emission computed tomography (SPECT), these techniques vary considerably regarding precision, ease of use, availability, and costs [4].

The functional status of the left ventricle represents the major predictor of long-term survival after recovery from acute myocardial infarction. Left ventricular function has usually been usually described in terms of the ejection fraction (EF) [5-8].

Studies from the database of Cedars-Sinai Medical Center (Los Angeles, Calif) demonstrated that post-stress EF and ESV, obtained by Tc-99msestamibi gated SPECT, provide significant information over the extent and severity of perfusion defects in prediction of cardiac death[9].Furthermore, the ESV provided prognostic information over the post stress EF and improved stratification of patients into risk levels. A subsequent study demonstrated that the post-stress EF was the best predictor of cardiac death, whereas the amount of stress-induced ischemia was the strongest predictor of myocardial infarction [10]. Poor contractile function due to extensive myocardial damage and continuing ischemia may cause low EF while the left ventricle dilation is caused by infarct expansion and stretching of the myocardial scar. Therefore end-systolic volume (ESV) or end-diastolic volume (EDV) might be more meaningful predictors of prognosis than EF, which is merely an arithmetical term based on these two Values [11].

Ejection fraction

Left ventricular (LV) ejection fraction (LVEF) is an ejection phase index that is commonly used in the diagnosis and management of cardiovascular disease.12–14moreover; it provides valuable prognostic information for many cardiac disorders [15]. Multiple diagnostic techniques have been utilized to measure LVEF including invasive contrast left ventriculography(ICLV), two-dimensional echocardiography (2DE), quantitative gated single-photon emission computed tomography (g-SPECT), first pass and equilibrium radionuclide left ventriculography, cardiac magnetic resonance imaging, and computed tomographic angiography [14,16–17]. LVEF is routinely measured in patients with established coronary artery disease and is often obtained during the evaluation of patients with chest pain [16–17].

In patients with myocardial disease the accurate and a reliable determination of the left ventricular ejection fraction (LVEF) is critical for the prognosis, risk stratification, and therapeutic management [18]. The unique ability to assess both myocardial perfusion and LV function is offered through gated single photon emission tomography (GSPECT) [19]. Previous studies demonstrated a high serial reproducibility of rest quantitative gated SPECT (QGSPECT) LVEF [20–22], end-diastolic volume (EDV), and end-systolic volume (ESV), as well as a high correlation of rest and stress QGSPECT measurements with those obtained by first-pass or exercise radionuclide angiography[22, 23], 2-dimensional echocardiography [24, 25], contrast ventriculography [26, 27], and magnetic resonance imaging [28]. Although the perfusion information acquired by the gated SPECT reflects perfusion at the time of injection, the ventricular function data occur at the time of the acquisition [29]. As a result, the ventricular function generally reflects the resting condition of the myocardium whether the patient is injected at rest or stress [30].

The time after stress when the SPECT acquisition is commenced is one factor that may enable a conclusion about whether the functional information is considered resting or post-stress [31].

Moreover, a large body of evidence suggests that functional information acquired after stress is different from that acquired at rest. Consequently, the American Society of Nuclear Cardiology recommends that gated SPECT should be performed on both stress and rest studies [32].

Problem of the study

Electrocardiogram-gated SPECT measurements of EDV, ESV and EF show high correlation with cardiac MRI measurements, but substantial errors may occur in individual patients(J Am Coll Cardiol 2002;39:2059–68) © 2002 by the American College of Cardiology Foundation).

So Electrocardiogram-gated SPECT has a hight dose to the patient, In addition to the relatively high costs, data processing is also time-consuming and stress test may increase illnesses to the heart.

MATERIAL AND METHODS

Materials that using was Gamma Camera (SPECT), Dose Calibrator, Radiopharmaceutical TC 99m (sestamibi), Electrocardiogram (ECG), Sphygmomanometer and IDL program. Study consists of 60 random patients with suspected from myocardial infarction. patients has been given 8-30 mci of TC 99m- MIBI intravenously, and fasting for 12 hours before examination and stop any caffeine for 3 days, ECG in place patient in supine position, heart in the center of field of view 00, camera position at 450 start imaging after 40 minutes from injection of radiopharmaceutical with ECG.

The SPECT images manipulated by a function written in IDL software to transfer it to gray scale image and the total account of brightness is 100 then the function normalize the image using the range of count that describe the muscles of the heart to four categories as normal, mild, moderate and sever. Then after recognition of each part on the image, same process applied on the subsequent slice for the whole heart, then the number of pixel in each tpart were counted to find the percentage of the heart classes (normal, mild, moderate and sever) and calculate the (ESV, EDV and EF) in case of heart at stress and calculate correlation between them to find equation that describe (ESV, EDV and EF) without doing stress test.

RESULTS

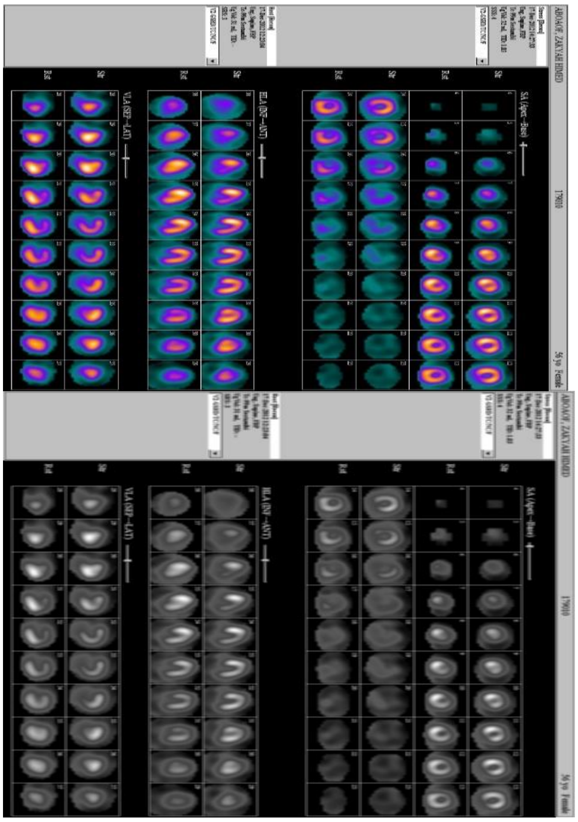

Fig.1. show the SPECT original image of the heart up (colored image) and down show the image after applying the IDL function to transfer it to gray scale image

Table-1: Normalized count of the heart (heart class) in the rest and stress status

Status	Normal	MILD	MODRATE	SEVER
Rest	10.60±2.41 (6.32 -16.77)	19.31±9.10 (7.34 – 41.09)	50.24±7.39 (31.71 – 61.71)	19.81±4.83 (11.42 – 31.98)
Stress	10.22±2.37 (4.70 – 13.97)	17.87 ± 7.42 (5.97 – 34.45)	49.82 ± 5.90 (39.37 – 61.56)	21.55±4.66 (11.71 – 29.53)
Total	10.47 ± 2.39 (4.70 – 16.77)	18.83 ± 8.55 (5.97 - 41.09)	50.10 ±6.89 (31.71 – 61.71)	20.39 ± 4.81 (11.42 – 31.98)

Table-2: Ejection fraction, end diastolic volume and end systolic volume of the heart in the stress status

Status	Mean	STD	Minimum	Maximum
EF	64.67	13.99	38	85
EDV	91.12	32.07	36	148
ESV	36.29	24.41	7	92

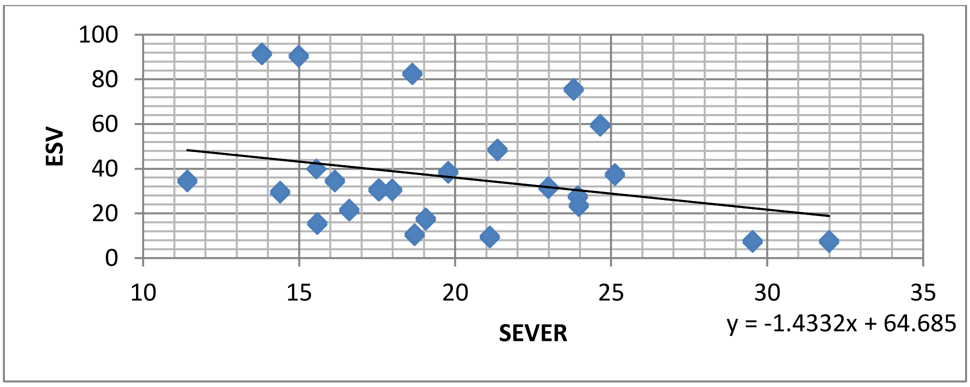

Fig-2: show direct inverse linear relationship between sever normalized count of the heart and end systolic volume

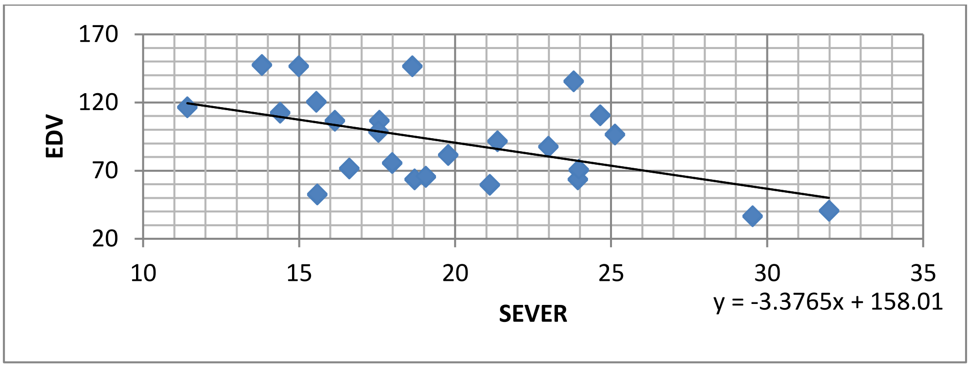

Fig-3: show inverse linear relationship between sever normalized count of the heart and end diastolic volume

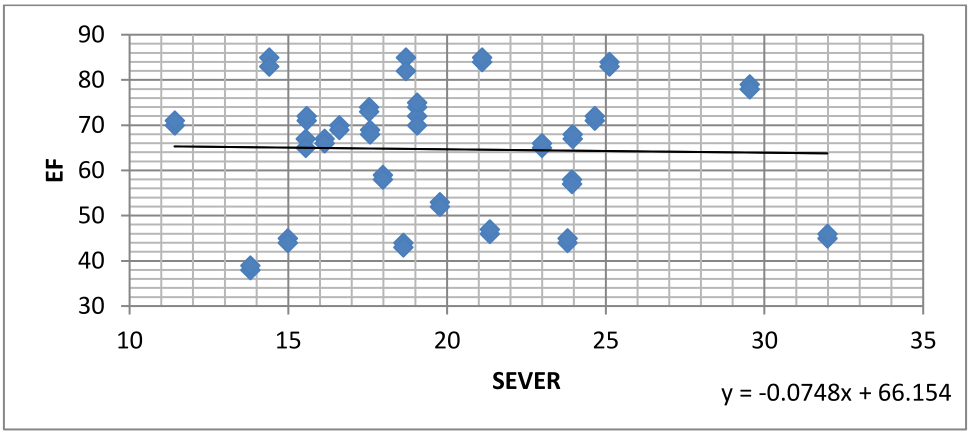

Fig-4: show direct inverse linear relationship between sever normalized count of the heart and ejection fraction

DISCUSSION

SPECT images manipulated by a function written in IDL software to convert it to gray scale image and the total account of brightness is 100 then the function normalize the image using the range of count that describe the muscles of the heart to four classes as normal, mild, moderate and sever. after recognition each part of image, same process applied on the subsequent slice for the whole heart, then the number of pixel in each part were counted to find the percentage of the heart classes as normal, mild, moderate and sever **fig1**, the statistical results shows as mean± SD and minimum, maximum value using paired sample t-test, in normal status at rest 10.60±2.41and in stress the value is 10.22±2.37, in Mild at rest 19.31±9.10and at stress 17.87 ± 7.42, and moderate the mean value at rest 50.24±7.39and at stress 49.82 ±5.90, and the sever situation at rest 19.81±4.83 and at stress 21.55±4.66as shown in **table 1.**

Inverse linear relationship between sever normalized count of the heart and end systolic volume, the ESV decrease by 1.43 per one unite of the normalized count for the sever class, this means that as long as the sever portion in the heart increase the strength of the heart muscles decrease and hence the amount of the blood entering the heart will be reduced to up normal level fig (2).

Inverse linear relationship between sever normalized count of the heart and end diastolic volume, the EDV decrease by 3.37 per one unite of the normalized count for the sever class, this means that as long as the sever portion in the heart increase the strength of the heart muscles decrease and hence the residual amount of the blood in the heart basically up normal will be reduced but also to the up normal level fig (3).

The EF decrease by 0.074 per one unite of the normalized count for the sever class, this means that as long as the sever portion in the heart increase the EF will be decreased as an up normal process fig (4).

CONCLUSION

This study aim to estimate the End-diastolic Volume, End-systolic Volume and Ejection Fraction of the heart in myocardial perfusion imaging (SPECT) at the heart in stress status test from the heart at rest status test using a function written in IDL software to normalize the image to range of count that classify the muscles of the heart to four classes normal, mild, moderate and severe, and recognize each part of the images as one of the classes. Therefore this study shows that we can estimate the (End-diastolic Volume, End-systolic Volume and Ejection Fraction of the heart) at stress status test from rest status test without stressing the patient using the following linear equations:

Equation for the regression values to estimate the Ejection Fraction, End-diastolic Volume and End-systolic Volume and:
Ejection Fraction = -0.0748(normalized count for the sever class) + 66.154
End-diastolic Volume = -3.3765(normalized count for the sever class) + 158.01
End-systolic Volume = -1.4332(normalized count for the sever class) + 64.685

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