Assessment of cardiac function using myocardial perfusion imaging technique on SPECT with $^{99m}$Tc sestamibi

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Abstract. Suspicion on coronary heart disease can be confirmed by observing the function of left ventricle cardiac muscle with Myocardial Perfusion Imaging techniques. The function perfusion itself is indicated by the uptake of radiopharmaceutical tracer. The 31 patients were studied undergoing the MPI examination on Gatot Soebroto Hospital using $^{99m}$Tc-sestamibi radiopharmaceutical with stress and rest conditions. Stress was stimulated by physical exercise or pharmacological agent. After two hours, the patient did rest condition on the same day. The difference of uptake percentage between stress and rest conditions will be used to determine the malfunction of perfusion due to ischemic or infarct. Degradation of cardiac function was determined based on the image-based assessment of five segments of left ventricle cardiac. As a result, 8 (25.8%) patients had normal myocardial perfusion and 11 (35.5%) patients suspected for having partial ischemia. Total ischemia occurred to 8 (25.8%) patients with reversible and irreversible ischemia and the remaining 4 (12.9%) patients for partial infarct with characteristic the percentage of perfusion ≤50 %. It is concluded that MPI technique of image-based assessment on uptake percentage difference between stress and rest conditions can be employed to predict abnormal perfusion as complementary information to diagnose the cardiac function.

1. Introduction

Coronary heart disease is one of the causes number of death in Indonesia. The malfunction heart is caused by constriction of the coronary arteries. If the heart could not pump blood and distribute it’s to all parts of the body, pain in the chest will be happen while heavy work or walk a rush. Heart disease has caused death 26.4% of all mortality in the country in 2001 according to the Health Survey Indonesia [1]. Nuclear cardiology as a diagnostic procedure is commonly used to evaluate coronary artery disease. Nuclear cardiology is dedicated for cardiac function assessment, metabolism and to observe the images of the left ventricle of the heart which is often used in clinical evaluation [2].

Myocardial perfusion imaging (MPI) techniques is an ideal approach to doing the assessment of myocardial perfusion. As non-invasive imaging modalities, it can examine the functions of the various segments of the heart muscle to reflect whether there is a malfunction on coronary arteries. In myocardial perfusion imaging studies, there are stress and rest sets of data [3]. The study of stress patient data was obtained from exercise using a treadmill or pharmacological stress agent. Furthermore, the study of rest patient data was gained with the patient in complete resting condition on the same or different day, and then it is injected after satisfying all these conditions [4]. Evaluation carried out by observing the distribution of myocardial activity shown on bull eyes that illustrate image 2D polar map [5].
Radionuclide Thallium 201 ($^{201}$Tl) and Technetium 99m ($^{99m}$Tc) have become the most widely used in MPI procedure [5]. Radionuclide $^{201}$Tl that is produced in the cyclotron has long half-life ($t_{1/2} = 73$ h) and low energy photon (60 to 83 keV) therefore, the image results have low resolution, great scatter and attenuation. Radionuclide $^{201}$Tl has been abandoned for assessment of myocardial perfusion which it. In 1990, radionuclide $^{99m}$Tc have been introduced of utilization for the assessment of myocardial perfusion [1]. Several characteristics of this radionuclide provided clear advantages over $^{201}$Tl for gamma camera imaging. Compare to radionuclide $^{201}$Tl, radionuclide $^{99m}$Tc is produced through a generator which have higher energy (140 keV) and that is ideal for standard gamma camera imaging with lesser scatter and attenuation, and shorter half-life ($t_{1/2} = 6$ h) [6]. Radionuclide $^{99m}$Tc will be labeling pharmaceutical methoxyisobutyl isonitrile (sestamibi) that is commonly used to study perfusion myocardial [6]. Radiopharmaceutical $^{99m}$Tc-sestamibi would accumulate in the myocardial tissue of the bloodstream. 

SPECT imaging is a tomographic technique that provide three-dimensional (3D) heart organ for given information of uptake radiopharmaceutical on each segment of the heart [4]. In this study will be informed evaluation the image of left ventricle to assess function cardiac-based on myocardial perfusion imaging technique. By quantifying of radiopharmaceutical uptake of $^{99m}$Tc-sestamibi by every segment illustrated in the bull eyes, the percentage of myocardial perfusion was determined as described in figure 2.

2. Materials and methods
In this research, 31 patient in records were examined with SPECT myocardial perfusion at the Department of Nuclear Medicine, Hospital Gatot Subroto Jakarta between February and June 2015. The patients were suspected of suffering from disorders of the heart muscle were used as a data sample in this work. Patient data were taken which used $^{99m}$Tc sestamibi perfusion and the percentage obtained under conditions of stress and rest. SPECT imaging scans performed with dual head with LEGP collimator and detector NaI(Tl). Patient examination was done in 1 day with 2 phases of stress and rest protocol [5].

2.1. Protocol stress
Stress testing the heart organ in myocardial perfusion imaging techniques are through physical exercise (ergometric) and pharmacologic. Conditions stress will cause an increase in oxygen consumption in the heart muscle tissue [2]. Increased myocardial perfusion are characterized by heart rate, blood pressure and myocardial contraction, resulting in coronary artery vasodilation [7]. Myocardial perfusion can also enhance through the provision of pharmacologic Persantine. There is occurred differential capacity of dilation of blood vessels so that the tracer can be identified as cardiac dysfunction. When stress testing was done, it is necessary to observe the heart rate on the computer check the condition of the patient such as heart rate recovery in the initial conditions. Radiopharmaceutical injection can perform after the heart rate has reached 85 percent of the difference between 220 minus the age of the patient [7]. Radiopharmaceutical was injected with the range of dose between 259 to 333 MBq [3], and then patients were encouraged to consume a large amount of fat so that no distortion of the image of the heart of the surrounding organs.

![Figure 1. The images of the heart organ is mapped into 2-dimensional to called bull eyes.](image-url)
2.2. Protocol rest
Testing rest was done after 2 to 4 hours of scanning images under stress completed [5]. The test was done by using radiopharmaceutical injection with doses greater than the stress condition in the range 629 to 814 MBq [3]. Afterward, the scanning will perform with the same parameters SPECT which was using in protocol stress.

2.3. Scanning and acquisition SPECT
The patient in the supine position with both arms placed on the head and the electrodes attached to the patient's body to observe the heart rate [8]. Scanning was done with dual head SPECT gamma camera parameters Cardiac Gated SPECT. This study were applied parameters zoom 1.46 x (40.9) cm, matrix size 64 x 64, the number of angles 64, time per angle 20 seconds, the saturation level of 32.767, the relative angle detector 90°, the initial angle of 45°, and the direction of rotation clockwise.

SPECT gamma camera detector was positioned on the patient's body left chest. The detector was rotated 180 degrees from the position of 45 degrees right anterior oblique (RAO) to 45 degrees left posterior oblique (LPO) [8]. Both detectors are perpendicular, with a position as close as possible to the body of the chest, which is located in the middle of the field of view (FOV) detector.

The result of scanning are a reconstruction of the left ventricle and then we did the quality control image acquisition with cine display [9]. The reconstruction was done with applications Philips Astonish Cardiac Gated SPECT Auto Pro that can directly doing to correction of attenuation, scatter, and partial volume effect. This application provided a correction resolution, minimize noise and improved uniformity. Moreover, the scanned image would be reconstructed to determine the boundary around the heart to the organs. Automatic segmentation in cardiac image reconstruction program could make the slide image from the volumetric data. The evaluation of slice image was performed by Quantitative Perfusion/Gated SPECT (QPS/QGS) from Cedars-Sinai Medical Center, Los Angeles [4]. The volumetric image was segmented into three slices, namely the short axis, vertical long axis, and horizontal long axis for each condition of stress and rest as illustrated in figure 2 [2].

QPS method used ellipsoidal models to identify myocardial, heart can be assessed visually quantify 3D distribution approach in myocardial activity. It uses cylindrical and spherical coordinates so that it becomes a 2D map of the image is called bull eyes [4]. The bull eyes were divided into 5 regions of the left ventricle heart, there is anterior, lateral, inferior, septal and apex [5]. Tracer each area will be displayed in the interpretation of the percentage of perfusion in the color scale [10]. The color scale ranges from 0 to 100 percent, a higher percentage of myocardial perfusion showed good function, and conversely, a lower percentage indicates abnormal myocardial function.

Myocardial function was determined by observation of concentration of tracer uptake, and proportional to the percentage myocardial perfusion [2]. Tracer uptake on stress condition must be greater than rest condition. Conversely, it suspected abnormal myocardial perfusion function. Diagnosis of abnormal function can be determined from the defining difference between the percentage perfusion of stress and rest conditions. The percentage difference (Δ) of the segment of the heart wall has been used to assess the left ventricular function.

Observations percentage of cardiac perfusion of the left ventricle, infarction in coronary artery occurred if the percentage perfusion is less than 50 percent. Myocardial necrosis happens due to blood flow in the coronary arteries stalled consist of myocardial infarction viable (reduced perfusion between stress and rest is not significant in the range of 0 to 20 percent) and nonviable infarction (decrease stress and rest perfusion is in the range of 21 to 50 percent). Furthermore, we considered percentage difference (Δ) between stress and rest based on the percentage of perfusion in between 51 to 100 percent for each segment. If the percentage difference (Δ) is a positive value, the myocardial blood flow tends to normal, but if the percentage difference (Δ) is a negative value tend to ischemia symptom. Ischemia could be categorized in reversible (if the percentage difference between stress and rest more than 20 percent) and irreversible (if the percentage difference about of 0 to 20 percent) [2, 4, 10].
3. Results and discussion

The average of patient age is 59 ± 11 years with a range of 42 to 72 years from 31 patients with 17 males and 14 females. Examination load procedure for the patient is expected to pass the activities ergo cycle to see a heart function, but there were 2 patients are unable to do it because 1 patient had a stroke and 1 patient a new surgery on the right foot. Therefore, two patients were given pharmacological Persantine to make heart muscle dilatation.

Figure 3. Graphic assessment of perfusion percentage of each segment to all patients, by parameter: 5 normal; 4 irreversible ischemia; 3 reversible ischemia; 2 nonviable infarct; 1 viable infarct

Patient data was evaluated by QPS program to obtain a percentage of left ventricular perfusion and divided into five segments; anterior, apex, lateral, inferior and septal as illustrated in figure 3. For anterior segment showed 10 normal patients and 21 patients with abnormal, there were 18 patients with ischemia irreversible \((\Delta = 2 \text{ to } 10\%\)), 1 patient ischemia reversible \((\Delta = 13\%)\), and 2 patients infarction nonviable (percentage perfusion 26 and 45%). The lateral segment showed 12 normal patients and 19 patients with perfusion abnormalities, there were 14 patients with ischemia irreversible \((\Delta = 1 \text{ to } 8\%)\), 4 patients with ischemia reversible \((\Delta = 11 \text{ to } 18\%)\), and 1 patient infarction nonviable (percentage perfusion 40%). The inferior segment showed 10 normal patients and 21 patients with abnormal perfusion which are 18 patients with irreversible ischemia \((\Delta = 1 \text{ to } 6\%)\), 1 patient with ischemia reversible and 2 patients with infarct nonviable (percentage perfusion 41 and 45%). The septal segment showed 12 normal patients and 19 patients with abnormal perfusion which are 17 patients with irreversible ischemia \((\Delta = 1 \text{ to } 8\%)\), 1 patient irreversible ischemia \((\Delta = 14\%)\) and 1 patient infarction nonviable (perfusion percentage of 36%). And the last segment, apex segment showed 12 normal patients and 19 patients with perfusion abnormalities which are 13 patients with irreversible \((\Delta = 1 \text{ to } 12\%)\).
10%), 2 patients with reversible ischemia ($\Delta = 13$ to 16%) and 4 patients with infarction nonviable (15 to 36%).

Assessment allegations with MPI technique can be followed by observing the five segments of each patient, the average assessment of each segment of the anterior, lateral, inferior, septal and apex show that allegation of 8 patients with normal perfusion (consisting of 4 to 5 segments of normal), 11 patients with partial ischemia (there are 2 to 4 ischemia reversible and there are at least 1 normal), 8 patients total ischemia (segment consists ischemia reversible and irreversible) and 4 partial infarction patients (there are 2 to 3 nonviable infarction). Abnormal perfusion is resulting that created to allegations of partial ischemia, total ischemia, and partial infarction because of tracer uptake stress condition less than rest condition cardiac. In stress condition heart is increased of perfusion blow flood on left ventricle of cardiac. It is demonstrated on the image and be evidenced of percentage perfusion every segment of left ventricle.

If the myocardial wall segment is associated with coronary artery, segments of the anterior and lateral indicating the left coronary, inferior segment indicating the right coronary and lateral segment indicating the circumflex arteries [9]. Most likely, the abnormality of heart due to blockage in a coronary artery or branches left artery [2]. Five segments of the left ventricle, anterior has the biggest risk factor in the process of perfusion because the location of anterior is front of the heart muscle and very active with the function to pump blood. All segments of myocardial wall showed nearly equal amounts in the diagnosis that means less in perfusion, and then it will be discussed by a cardiologist for further medical action.

4. Conclusion
Myocardial Perfusion Imaging (MPI) techniques can be used to diagnose the function muscle heart of the review perfusion blow flood cardiac. Based on the uptake segment of the left ventricle, it shows the scanning image described the percentage perfusion. The assessment uptake of percentage perfusion is predicting abnormal perfusion, for example, ischemia or infarct.

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