Myocardial perfusion SPECT: Perfusion quantification

Review Article

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ABSTRACT

Different software tools for quantification of myocardial perfusion SPECT (MPS) studies are routinely used. Several perfusion parameters can be computed automatically. Interpretation of the MPS should start with visual inspection of the rotating planar images, visual analysis of reconstructed SPECT slices and then quantitative analysis to confirm the visual impression. Quantification should be used routinely as complementary to visual analysis. Advantages of quantification are: greater confidence in interpretation, better reproducibility, diagnostic accuracy and measuring the degree of abnormality even subtle changes for serial comparisons. In this review, we look at the common features of such quantitative tools: 17-segment scoring system, polar maps including: raw, severity and extent polar maps, lung-to-heart ratio, transient ischemic dilation ratio, total perfusion deficit and spherecity index.

Key words: Myocardial perfusion SPECT; Perfusion quantification; Polar map; Scoring system

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INTRODUCTION

Assessment of myocardial perfusion SPECT (MPS) is done not only visually but also by a number of semi-quantitative measures using various computer software. Quantification tools objectively determine myocardial perfusion abnormality using abnormality thresholds based on a reference normal data base. These automated tools increase diagnostic reproducibility & accuracy and reduce interobserver variability [1].

As Watson [2] has said, after measurement of tracer uptake (perfusion) and comparison with a normal population data, quantification tools classified MPS as normal or abnormal. However, interpretation of the study as the presence or absence of significant coronary artery disease (true abnormality) is important [2]. For example, a 64% of the maximum myocardial tracer uptake in the anteroapical segment may be below the abnormal threshold and interpreted as abnormal. The defect could indicate a true myocardial perfusion defect secondary to coronary artery disease (CAD), but it could also be an artifact as a result of motion, attenuation, defective photomultiplier tube or center of rotation off-set, and so forth. So, an expert nuclear medicine physician as an interpreter is required [2]. Indeed the computer software quantification is an aid for more reproducible diagnosis and increased diagnostic accuracy.

Scoring System

It is recommended that at least a segmental scoring system be used for report of MPS. In segmental scoring systems, the perfusion scores incorporate defect extent and severity in a single parameter, which have important prognostic significance [1, 3] Based on AHA and ASNC recommendation, it is better to use 17-segment scoring system rather than 20-segment model, as this model provides the best agreement with other imaging modalities such as MRI, echocardiography and anatomical data [4] (Figure 1).

It is possible to measure the perfusion scores visually or using quantification tools. Segments are assigned severity perfusion scores according to a 5-point scale: 0 = normal; 1 = mildly reduced; 2 = moderately reduced; 3 = severely reduced; 4 = absent uptake) [5, 6] (Figure 2).

Summing the all segments scores produce the summed scores, which are calculated for stress (Summed Stress Score: SSS), rest (Summed Rest Score: SRS), and the difference between stress and rest (Summed Difference Score; SDS). The summed difference score is analogous to reversibility indicating stress-induced myocardial ischemia [1, 5, 7]. With increase in summed scores (worsening of the scan abnormalities) cardiac events will increase. A summed stress score of less than 4 is considered as normal limits while 4-8: mildly abnormal, 9 to 13 a moderate abnormality, and over 13 large perfusion abnormality [8].

It is possible to convert the summed scores to estimation of percent myocardial abnormality. It is calculated by dividing the summed scores to the worst segmental score possible (not any tracer uptake throughout the LV myocardium) in the specific model used (68 for 17 segments) and multiplying by 100 [9].

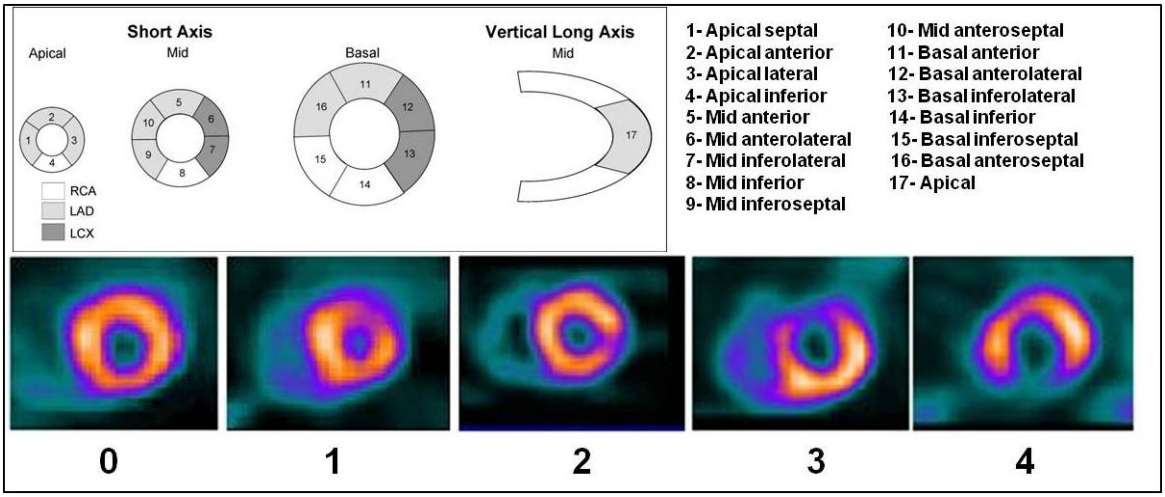

Fig 1. 17-segment scoring system: 17 segments (row above) and example of scores (row below): 0 = normal; 1 = mildly reduced; 2 = moderately reduced; 3 = severely reduced; 4 = absent uptake.

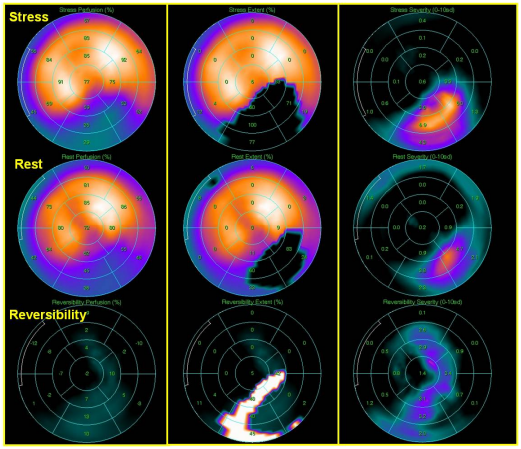

Fig 2. Raw polar maps shows decreased tracer uptake in the inferior and inferolateral segments with more pronounced in the stress phase (Left column). Extent polar map shows blackout pixels in the inferior and inferolateral segments with more extent in the stress phase. Reversibility extent polar map showed a whitened out (white color) in the apical inferior, apical lateral and mid & basal inferior segments (Middle column). Severity polar map shows severity of hypoperfusion based on SDs below the normal using a color scaling system (Right column).

Polar Maps

Polar maps provide a 2-D representation of the 3-D myocardium. Although many algorithms use cylindrical sampling around the body of the left ventricle (basal and midventricular LV walls), the methods differ in their samplings of the apical region [10]. Many software use a spherical pattern to form a cap over the apex of the LV [2]. The ellipsoid approach for whole LV myocardium is another approach [11]. In a polar map, anterior LV wall tracer activity is at the top and the septal wall at the left. The center of the polar map representing the apex and the basal portions of the LV walls are at the peripheral circumference [10]. There are three common types of polar maps: Raw, Extent and Severity polar maps. These types of polar maps are computed for each phases of the study: Stress and Rest phases as well as for reversibility between these two phases [2, 12].

Raw Polar Map: The quantification of myocardial tracer uptake is relative in nature and therefore image counts were normalized to a common level before the comparisons are made [6]. Raw count was displayed in this polar map. A pixel in a polar map with maximum count considered as 100% and other pixels are normalized to this hottest pixel. We can see average raw pixel value based on the myocardial segments, territory or wall [12]. The raw reversibility polar map is built pixel by pixel from the stress and rest raw maps. It is calculated as normalized rest values minus normalized stress values [10, 12]. If there is reversibility < 0, it is considered as 0 [12].

Extent Polar Map (Blackout Polar Map): The "blackout" polar map set those pixels in the polar map to the color black that contain counts lower than a certain threshold below the normal mean for that pixel (eg, more than 2.5 SD below normal) while other pixels have the same intensity in the Raw map[1,12]. In the blackout polar map, we can see quickly abnormal defect location and size [1]. Myocardial perfusion defect extent can be expressed as a percent value of the entire myocardium, or a percent value of the certain region: an individual vascular territory, a LV wall or a segment [6, 9, 12]. For computation of extent reversibility polar map, in raw reversibility map, pixels in the blackout area(s) of stress extent polar map will be blackout, except following pixels in this region are "whitened out": 1) if the difference between the severity at stress and rest is above a certain threshold, 2) if the homologous pixel at rest is not blacked out [12].

Severity Polar Map: In comparison with a normal data base, a local measure of the hypoperfusion severity can be defined as the number of standard deviations below normal mean [6, 12]. For color scaling display, the scale is linear in the 0-10 standard deviation range. It is possible to calculate the average severity for each segment, LV wall or territory. In other words, the local samples of hypoperfusion can be aggregated into regional (segment, territory or wall) or global measures [6, 12]. The severity reversibility polar map displays the results of rest - stress severity. It is calculated, pixel by pixel, as $Stress_{severity} - rest_{severity}$. Although the color scaling is limited to 0-10 in stress or rest severity polar map, the numbers are not constrained to the 0-10 range (presence of negative values or above 10). But in severity reversibility polar map, the numbers are constrained to 0-10 [12].

Total Perfusion Deficit (TPD)

TPD combines defect severity and extent in one continuous parameter to provide an overall measure of hypoperfusion [11]. Based on the degree of the pixel counts below the normal limit, a score is assigned to each pixel. Each polar map pixel score has automatically calculated from 0 to 4. In AutoQUANT, a score of 4.0 was assigned to all pixels more than 70% below the normal limit [12]. After that, the percent of the abnormality throughout the whole LV myocardium was calculated. The theoretical maximum value for total perfusion deficit is 100% for a case with no uptake in the entire myocardium.

The Lung-to-Heart Ratio (LHR)

LHR is a high risk variable in MPS. Normally no, or very little, radiotracer is noted in the lung regions on

postexercise images [8]. There is a linear correlation between the degree of lung uptake and pulmonary capillary wedge pressure at the time of tracer injection [11]. Increased lung uptake of radiotracer is associated with an elevated left ventricular end-diastolic pressure, exercise-induced ischemic left ventricular dysfunction and severe multivessel CAD [8]. In order to quantifying the LHR in the anterior or LAO the projection, maximal or mean pixel count in a reasonably small region of interest placed over the highest-count portion of the left ventricle and in a similar ROI in the pulmonary area, are used [11]. Normal lung-to-heart ratio is < 0.5 for ^{201}Tl and < 0.4 for ^{99m}Tc-labeled agents [8].

Transient Ischemic Dilation (TID)

TID is considered when the LV cavity appears to be larger in post-stress non-gated tomograms as compared to the rest images [11]. TID is a prognostic indicator of severe coronary artery disease [10]. Presence of TID can be assessed visually; on the other hand it is possible to quantification of TID ratio. TID ratio is calculated as the ratio of non-gated stress LV endocardial volume to non-gated rest LV endocardial volume [10]. Patients with more severe and extensive ischemia, multivessel-type of perfusion abnormality, LAD territory perfusion abnormality have more probability of presence of TID in their MPS [13]. Two proposed mechanisms for TID are: myocardial stunning as a possible cause of a true increase in LV size after stress-induced ischemia, and pseudodilation effect due to diffuse subendocardial ischemia [13-15]. However, the important issue is to determine the cut-off value for an abnormal TID ratio. It has been well documented that cutoff values for an abnormal TID ratio vary widely throughout the literature, ranging from 1.012 to 1.40 [13, 15]. We already derived abnormal threshold for automatically measured TID ratio in 2-day dipyridamole 99mTc-sestamibi MPS that to be >1.19 [14]. Abnormal TID ratio threshold is higher in females, vasodilator stress as well as dual-isotope studies [13, 15].

LV Shape

Pathologic remodeling of the LV is generally associated with a change from the normal shape to a more spherical geometry [11]. For assessment of LV shape changes, there are different proposed indices: Shape index (using gated diastolic and systolic images and calculation of end-diastolic and end-systolic shape indices), Eccentricity index (from 0: sphere to 1: line), and Sphericity index [11, 12]. Sphericity index can be estimated using 3-D LV surface and maximal distance between [1] two endocardial points in short-axis plane [2] the apical endocardial point and the center of the valve plane. This index is a good predictor of the future development of congestive heart failure [11].

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