Left ventricular ejection fraction from gated SPET myocardial perfusion studies: a method based on the radial distribution of count rate density across the myocardial wall

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Abstract. Left ventricular ejection fraction (LVEF) can be derived from gated single-photon emission tomographic (SPET) myocardial perfusion studies using either manual or edge detection techniques. In the presence of severe perfusion defects, however, difficulties may be encountered. In this article a method based on the assumption that the average position of the myocardial wall can be localized by means of statistical analysis of the distribution count density, and not on edge detection, is used to measure LVEF. SPET myocardial perfusion images, gated in eight time bins, were recorded in 50 patients 60 min after the injection of 925 MBq technetium-99m tetrofosmin. Masking of non-myocardial structures and thresholding resulted in images in which only myocardial walls had significant non-zero values. The distance of the wall relative to the centre of the cavity was calculated in the three-dimensional space as the first moment of the count rate distribution along radii originating in the centre of the cavity. LVEF was calculated using, for each time bin, the sum of the cube of all distances as an estimate of the cavity volume. The method required minimal operator interventions and was successful in all patients, including those with severe perfusion defects. Intraobserver and interobserver variability was excellent, with regression coefficients of 0.97 and standard deviations of 4.5% and 4.7%, respectively. For 30 patients, the measurements were validated against planar equilibrium radionuclide angiography (ERNA) that was obtained within an interval of 1 week. LVEF ranged from 12% to 88%. Agreement between the two methods was excellent (LVEFERNA=1.05+0.92 LVEFSPET, r=0.93, P=0.023, SEE=7.06). The Bland-Altman analysis did not show any apparent trend in the differences between ERNA and gated SPET over a wide range of ejection fractions. The standard deviation of the differences was 3.1%. In addition no relationship was found between the two methods and the severity of perfusion defects. In conclusion, accurate measurements of LVEF are obtained from gated SPET perfusion images using a method based on statistical analysis of the count rate density. This method did not deteriorate even in the presence of severe perfusion defects and could therefore be used in following patients after myocardial infarction.

Key words: Ejection fraction – Gated single-photon emission tomography – Myocardial perfusion


Introduction

Several recent studies have shown that left ventricular ejection fraction (LVEF) can be measured with reasonable precision from gated single-photon emission tomographic (SPET) myocardial perfusion images [1-5]. In these studies, the limits of the left ventricular cavity were outlined either manually following arbitrary thresholds [1] or by using edge [2, 4] or surface [5] detection algorithms. Although these techniques provide satisfactory results in many cases, difficulties may be encountered in the presence of severe perfusion defects where the myocardial contours cannot be identified accurately. In addition, estimation of the cavity volume requires additional geometric approximations.

A new approach to characterize myocardial wall kinetics from gated perfusion SPET studies has recently been developed at Stanford University [6]. In this method the location of the myocardial wall is defined by statistical parameters and not by edge detection. The algorithm operates in the three-dimensional space, radially from the centre of the left ventricular cavity. The sum of the cube of all distances to the myocardial wall is used to calculate the volume of the cavity.
The aim of this work was to determine the feasibility, reproducibility and accuracy of this method for measuring global LVEF in patients with coronary artery disease. The results were validated against LVEF measured on conventional planar equilibrium radionuclide angiocardiography (ERNA).

**Materials and methods**

**Patient population**

Included in this study were 30 consecutive patients with known or suspected coronary artery disease who underwent, for clinical purposes, both myocardial SPET imaging and radionuclide angiocardiography within an interval of 1 week. All patients were in a clinically stable condition and were in sinus rhythm at the time of the investigation. There were 13 men and 17 women with a mean age of 69.1±11.5 years. Twenty-one patients (70%) had a history of previous myocardial infarction. There were ten patients with anterior infarction and 11 with inferior infarction. Eighteen patients showed evidence of transmural (Q waves) infarction on standard 12-lead ECG.

Gated SPET myocardial perfusion studies from 20 patients with a less than 5% likelihood of coronary artery disease were also analysed [7]. These patients comprised seven men and 13 women with a mean age of 47.0±9.9 years. All of them had normal rest and exercise ECG, normal chest X-rays and normal 2D-echocardiographic studies.

**Measurement of LVEF from gated SPET perfusion images**

**Gated SPET acquisition.** Patients received 925 MBq of technetium-99m tetrofosmin intravenously at rest. Studies were acquired 60 min after tracer administration to a triple-head gamma camera (MultiSpect3, Siemens, Inc., Hoffman Estates, Ill.) equipped with low-energy high-resolution collimators. Acquisition parameters were 360° rotation, 32 views per head (96 angles), 64x64 format, zoom 1.23 (pixel size: 4.96 mm x 4.96 mm), stop and go, 40 s per stop, 8 time bins, forward/backward framing by 75% and beat acceptance window at 20% of the average RR interval calculated just before starting the acquisition. Patients with more than 15% rejected beats were not included in the study.

**Image preprocessing.** Gated projections were first normalized to the one containing the largest number of accepted beats. Transverse slices were then reconstructed by using the filtered backprojection method (Butterworth filter, cut-off frequency 0.4 cycles/pixel, order 5) and reoriented with respect to the left ventricular long axis. For each time bin, the images were then interpolated in the three-dimensional space by a factor 4 and displayed in the three orthogonal planes with the apex pointing downwards.

**Masking and thresholding.** Gated images were masked and thresholded in order to obtain data in which only the left ventricular wall had significant non-zero values. The right ventricle and non-cardiac structures were masked out by using a three-dimensional ellipsoidal mask fitted manually around the left ventricle. Thresholding was performed by subtracting from each pixel the average count density measured in a small region of interest (5x5 pixels) drawn at the base of the left ventricular cavity on the end-diastolic bin.

**Calculating the ejection fraction.** The theoretical bases of the method used in this study have been previously described in detail [4]. For each time bin the myocardial wall was sampled in three-dimensional coordinates along radii originating in the centre of the left ventricular cavity (Fig. 1). The first moment of the count rate distribution along each radius was used to calculate the average position of the wall (Fig. 2). If the distribution of count rate densities along radius R is C(R), the average position of the wall D is given:

$$D = \frac{\Sigma r C(r) dr}{\Sigma C(r) dr}. \quad (1)$$

The longitudinal angle of the radii originating in the centre of the cavity varied from 0° to 360° and the latitudinal angle from 0° (apex) to 135° in 32 steps. The sampling arc did not go beyond 135° to avoid sampling the left ventricular outflow tract where myocardium is absent. Along each radius, the average position of the wall (D) was calculated using Eq. 1. For each time bin, the sum of the cube of all D values was used as an estimate of the cavity volume (V):

$$V = \Sigma V^3. \quad (2)$$

The largest and the smallest V values were considered to be the end-diastolic (ED) and the end-systolic (ES) estimates of the cavity volume and used to calculate LVEF:

$$\text{LVEF} = (V_{\text{ED}} - V_{\text{ES}}) / V_{\text{ED}} \times 100. \quad (3)$$

**Quantification of myocardial perfusion defects**

Myocardial perfusion defects were identified on the end-diastolic images and quantified on distance-weighted polar maps using the 20 patients with low likelihood of coronary artery disease as normal references. An index of the severity of perfusion defect was calculated as the sum of the differences between the normal mean minus 2 standard deviations polar map and the patient polar map.