Left ventricular shape index assessed by gated stress myocardial perfusion SPECT: Initial description of a new variable

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Background. **Ventricular remodeling is predictive of congestive heart failure (CHF). We aimed to automatically quantify a new myocardial shape variable on gated myocardial perfusion single photon emission computed tomography (SPECT) (MPS) and to evaluate the association of this new SPECT parameter with the risk of hospitalization for CHF.**

Methods and Results. **A computer algorithm was used to measure the 3-dimensional (3D) left ventricular (LV) shape index (LVSI), derived as the ratio of maximum 3D short- and long-axis LV dimensions, for end systole and end diastole. LVSI normal limits were obtained from stress technetium 99m sestamibi MPS images of 186 patients (60% of whom were men) (control subjects) with a low likelihood of CAD (<5%). These limits were tested in a consecutive series of 93 inpatients (85% of whom were men) having MPS less than 1 week after hospitalization, of whom 25 were hospitalized for CHF exacerbation. Variables associated with CHF hospitalization were tested by receiver operating characteristic curve and multivariate logistic regression analyses. LVSI repeatability was assessed in 52 patients with ischemic cardiomyopathy who had sequential stress MPS within 60 days after the initial MPS without clinical events in the interval between MPS studies. Control subjects had lower end-systolic and end-diastolic LVSIs compared with patients with CHF and those without CHF ($P < .001$). Receiver operating characteristic curve areas for the prediction of hospitalization as a result of CHF were similar for LV ejection fraction and end-systolic LVSI. End-systolic and end-diastolic LVSIs were independent predictors of CHF hospitalization by multivariate analysis; however, end-systolic LVSI had the greatest added value among all tested variables. Repeatability was excellent for both end-systolic LVSI ($R^2 = 0.85$, $P < .0001$) and end-diastolic LVSI ($R^2 = 0.82$, $P < .001$).**

Conclusion. **LVSI is a promising new 3D variable derived automatically from gated MPS providing highly repeatable ventricular shape assessment. Preliminary findings suggest that LVSI might have clinical implications in patients with CHF. (J Nucl Cardiol 2006;13:652-9.)**

Key Words: Diagnostic application • gated myocardial perfusion single photon emission computed tomography • left ventricular geometry • congestive heart failure

Previous imaging studies, mostly based on echocardiography, have revealed the clinical and prognostic importance of left ventricular (LV) geometry in the pathophysiology and symptomatology of congestive heart failure (CHF).[1-6] It has been assumed that LV shape is closely related to cardiac performance and that, as the normally ellipsoid LV shape transforms into a spherical shape in LV failure,[4] the pattern of LV contraction changes and mitral regurgitation often develops or worsens. However, almost all echocardiographic descriptions of these geometric changes have been 2-dimensional (2D) and do not take into account the actual 3-dimensional (3D) changes in LV geometry.[7]

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Gated myocardial perfusion single photon emission computed tomography (SPECT) (MPS) has the ability to provide operator-independent measurements of myocardial perfusion and function in 3 dimensions.[8] The 3D character of the data allows measurement of LV dimensions in any direction, thus potentially providing more precise information regarding the LV shape.

The objective of this study was to design a quantitative index of 3D LV geometry—the LV shape index (LVSI)—derived from gated MPS and assess its repeatability. A secondary goal was to explore a potential application of LVSI by examining a group of consecutive inpatients referred for rest/stress MPS.

METHODS

Study Population

The total study population comprised 331 patients. Normal limits of LVSI were determined from stress Tc-99m sestamibi MPS images of 186 consecutive patients (60% of whom were men as control subjects) who had a low likelihood of CAD (<5%), normal rest/stress electrocardiography, and normal stress MPS. Repeatability of LVSI was tested in a group of 52 patients who had sequential MPS acquired at baseline and 60 days later without clinical events in the interval between the MPS studies. These patients were in the placebo arm of the Vascular Endothelial Growth Factor in Ischemia for Vascular Angiogenesis (VIVA) trial.[9] LVSI was then applied in a consecutive series of 93 inpatients (85% of whom were men) who underwent clinically indicated MPS within 1 week after hospitalization, of whom 25 (26%) had a discharge diagnosis of worsening CHF (CHF group) and 68 (74%) were considered as the non-CHF group. Written informed consent, approved by the Institutional Review Board of Cedars-Sinai Medical Center, Los Angeles, Calif, was obtained from all study participants. The VIVA study population was previously described in detail.[9] All VIVA patients had stable angina and ischemic cardiomyopathy.

Imaging Procedure

All study population patients underwent dual-isotope rest thallium 201/stress Tc-99m sestamibi MPS as previously described.[10] Whenever possible, β-blockers and calcium channel antagonists were terminated 48 hours before testing and nitrates were stopped at least 6 hours before testing. Patients performed a symptom-limited exercise treadmill test or vasodilator (dipyridamole or adenosine) stress testing by use of standard protocols.[11,12] They were instructed not to consume coffee or other products containing caffeine for 24 hours before the test.

Acquisition Protocol

Gated MPS (100% acceptance window) was started 10 minutes after Tl-201 injection and 15 to 60 minutes after Tc-99m sestamibi injection. MPS used a noncircular 180° acquisition for 64 projections at 20 to 25 seconds per projection for Tl-201 and at 15 to 25 seconds per projection for Tc-99m sestamibi. The projection data were reconstructed into tomographic transaxial images via filtered backprojection and automatic reorientation.[13] No attenuation or scatter correction was used.

Gated short-axis images were further processed by use of quantitative gated SPECT software (QGS; Cedars-Sinai Medical Center); 3D LV contours were derived, and LV ejection fraction (EF),[8] as well as all of the LV geometry indices, were automatically calculated.

Image Interpretation

For the purposes of this study, we analyzed only poststress Tc-99m sestamibi MPS images. Semiquantitative visual interpretation was performed by use of the 20-segment model.[10,14] Each segment was scored according to a 5-point scoring system (0, normal uptake; 1, equivocal uptake; 2, moderate reduction of uptake; 3, severe reduction of uptake; and 4, absence of detectable tracer uptake). Summed stress scores were obtained by summing of the individual stress scores of the 20 segments.[15,16] These indices were converted to the percentage of the total myocardium[17] that was abnormal at stress (% Myo stress) by dividing the summed scores by 80, the maximum potential score in the 20-segment model (4 × 20), and multiplying by 100. MPS results were categorized by use of % Myo stress: % Myo stress of less than 5 was considered normal; % Myo stress of 5 to 10, mildly abnormal; and % Myo stress of greater than 10, moderately to severely abnormal.

LVSI

For the purposes of this study, we developed a novel algorithm for the assessment of the LVSI, defined as the ratio of the maximum 3D short- and long-axis dimensions of the left ventricle (Figure 1). For each short-axis plane, the maximum in-plane dimension of the left ventricle was determined from the raw 3D contours derived by the QGS algorithm, by use of the endocardial surface as the boundary and searching for the maximum distance between 2 endocardial points in a given short-axis plane. Subsequently, the maximum short-axis endocardial dimension was determined from all short-axis slices on end-diastolic images. The maximum short-axis endocardial dimension was also computed from end-systolic images, by measuring the distance between the endocardial points in the identical location where the maximum short-axis endocardial dimension was found on the diastolic frame. The maximum long-axis dimension of the myocardium was derived by calculating the maximum distance between the most apical point on the endocardial surface and the center of the valve plane. The maximum long-axis dimension was calculated independently for the end-systolic and end-diastolic frames. Finally, the LVSI was derived as the ratio of the maximum short-axis dimension to the maximum long-axis dimension separately for end-systolic and end-diastolic frames. Both end-systolic LVSI and end-diastolic LVSI were obtained from stress images.