

Quantitative Estimation of Left Ventricular Ejection Fraction from Mitral Valve E-Point to Septal Separation and Comparison to Magnetic Resonance Imaging

Jay R. Silverstein, MD, Nicholas H. Laffely, MD, and Robert D. Rifkin, MD*

This study tested the hypothesis that the mitral valve E point-to-septal separation (EPSS) can be used to quantify the left ventricular (LV) ejection fraction (EF) on a continuous scale rather than simply as “normal” or “reduced.” After excluding 5 patients with mitral valve prostheses, asymmetric septal hypertrophy, or significant aortic insufficiency, EPSS was measured in 42 patients by 3 independent observers on a cardiac magnetic resonance image identical to the echocardiographic parasternal long-axis view. In each patient, the reference standard LVEF was calculated from the magnetic resonance short-axis cross-sectional stack images by Simpson’s rule and ranged from 11% to 72%. For all 42 patients, linear regression revealed the relation magnetic resonance imaging (MRI) LVEF = 75.5 – 2.5 · EPSS (millimeters). Correlation between EPSS and the MRI LVEF for the 3 observers agreed closely, ranging from $r = 0.78$ to $r = 0.82$ (SEE 9 to 10), with similar regression coefficients. After blinded segmental wall motion scoring of the gated magnetic resonance cine images of the left ventricle in each patient, correlations, SEEs, and regression coefficients were found to be very similar in the 21 patients with the most homogenous wall motion, compared with the 21 patients with the most heterogenous wall motion. In conclusion, clinically useful quantitative prediction of the LVEF as a continuous variable can be obtained from the EPSS with a simple linear regression equation in a substantial portion of patients and may be a useful adjunct for assessment of LV function. © 2006 Elsevier Inc. All rights reserved. (Am J Cardiol 2006;97:137–140)

The echocardiographic estimation of the left ventricular (LV) ejection fraction (EF) continues to be a challenge in routine study interpretation.^{1,2} Technically sophisticated quantitative methods have shown inconsistent accuracy and require specialized analysis hardware and software, which has rendered them impractical for use in daily practice. Accordingly, most clinical readers rely exclusively on a visually based “educated guess” of the LVEF.³ The mitral valve E point-to-septal separation (EPSS) is a simple measurement that reflects LV function, but its use has been limited to a categorical classification of the LVEF as either normal or reduced on the basis of a threshold value of 8 to 10 mm.^{4,5} Our objective in this study was to test the hypothesis that the EPSS can provide more precise quantification of the LVEF as a continuous variable.

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We identified 47 patients from the database of the cardiac magnetic resonance imaging (MRI) laboratory that included an image plane corresponding to the parasternal long-axis echocardiographic view and a short-axis LV cross-sectional stack. Five patients were excluded because of significant aortic insufficiency, mitral prosthesis, annuloplasty, or se-

vere annular calcific disease. MRI scans were obtained on an Intera CardioVascular 1.5-T scanner (Philips Medical Systems, Best, The Netherlands). Standard planes for ventricular 4-chamber, LV outflow tract, and short-axis stacks of 9-mm cross-sectional slices covering the entire left ventricle were obtained at 25 to 30 phases/cardiac cycle gated to the electrographic R waves, corresponding to an echocardiographic frame rate of 30 to 40 frames/s. A balanced fast-field echo pulse sequence was used with a repetition time of 2.8 ms, an echo time of 1.4 ms, and a flip angle of 50°.

Early diastole was reviewed frame by frame on the magnetic resonance image corresponding to the 2-dimensional echocardiographic parasternal view to find the maximal opening excursion of the mitral valve anterior leaflet. The EPSS was measured in millimeters as the minimal separation between the mitral valve anterior leaflet and the ventricular septum (Figure 1). The LVEF was computed by applying Simpson’s rule to planimetry of the end-systolic and end-diastolic short-axis MRI cross sections. The EPSS was measured independently by 3 observers, blinded to the LVEF, directly on tomographic magnetic resonance images of the LV outflow tract, corresponding to the parasternal long-axis echocardiographic view (Figure 1). Conventional correlation and regression analysis were used to analyze the relation between the LVEF by Simpson’s rule and the EPSS for each observer.⁶

To assess the effect of the homogeneity of wall motion on our results, we scored wall motion in a 12-segment model, as previously described, along the following contin-

Division of Cardiology, Department of Medicine, Barnes-Jewish Hospital, Washington University School of Medicine, St. Louis, Missouri. Manuscript received April 27, 2005; revised manuscript received and accepted July 26, 2005.

* Corresponding author: Tel: 314-747-0726; fax: 314-747-4758.

E-mail address: rifkin@im.wustl.edu (R.D. Rifkin).

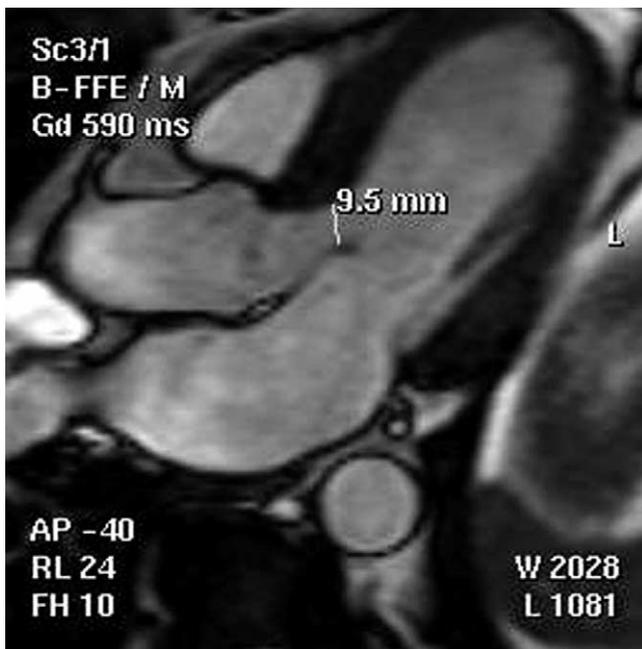


Figure 1. LV outflow MRI view corresponding to the echocardiographic parasternal long-axis view of the mitral valve. In this image, the mitral valve E-septal separation measured 9.5 mm, as shown by the line extending from the anterior mitral valve leaflet tip to the nearest border of the intraventricular septum. The aortic valve is to the *left* of this line and the LV cavity to the *right*.

Table 1

Regression equations for prediction of the LVEF from mitral valve EPSS

Observer	n	Regression Equation	Correlation Coefficient (r)	SEE
1	42	$LVEF = 75.5 - 2.5 \cdot EPSS$	0.82	9.5
2	42	$LVEF = 77 - 2.7 \cdot EPSS$	0.78	10
3	42	$LVEF = 77 - 2.6 \cdot EPSS$	0.80	9.9

uous scale: 0 = akinesia, 100 = normal, dyskinesia <0, and hyperkinesia >100.^{7,8} Scores were obtained by consensus of 3 observers separately from the EPSS measurements. We analyzed and compared the relation between the EPSS and the EF separately for the 21 patients with lowest and the 21 patients with the highest SDs of their scores.

Of the 47 patients with suitable images, 5 were excluded because of significant aortic insufficiency, mitral stenosis, or a prosthetic mitral valve. In the remaining 42 patients, the LVEF ranged from 11% to 72% (mean of $47 \pm 16\%$). The correlations between Simpson's LVEF and the EPSS LVEF for the 3 observers were (Table 1, Figure 2) $r = 0.82$ (95% confidence interval 0.69 to 0.9), $r = 0.78$ (95% confidence interval 0.62 to 0.88), and $r = 0.82$ (95% confidence interval 0.66 to 0.89). The correlation coefficients were all highly significant ($p < 0.0001$ for all 3 r values). SEEs ranged from 9.5 to 10. The regression equations obtained for the 3 independent observers (Table 1) were virtually identical, reflecting excellent agreement of the EPSS measurements. The correlation coefficients between the EPSS

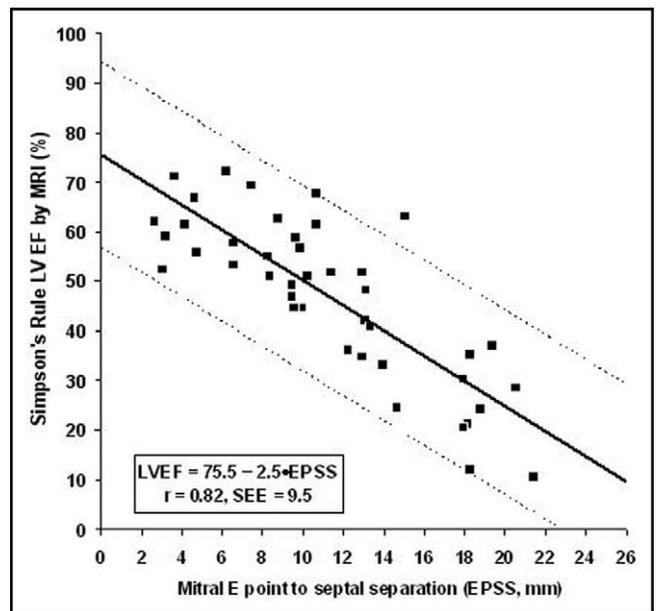


Figure 2. Scatterplot of the MRI LVEF versus the EPSS with regression line (solid line) and 95% confidence intervals about the regression line (dotted lines).

measurements of the 3 observers were 0.98, 0.92, and 0.93 with SEEs of 0.9, 2.1, and 1.9, respectively.

The regression equations for the 21 patients with the most homogenous versus the most heterogenous wall motion were very similar to each other and to that of the complete population (Table 2). The mean LVEF of the group with heterogenous wall motion scores was lower, as expected, because this group included more patients with segmental dysfunction and fewer with normal segmental function. However, the range and SD of the MRI LVEF in the 2 groups were very similar. The correlation coefficients in these 2 subgroups were lower than the overall population, but the SEs were the same. This was due to the smaller SD of the dependent variable (MRI LVEF) in the 2 groups (13.2 and 14.4) compared with the SD of the MRI LVEF in the full population.⁶

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Our goal in this study was to test whether the mitral valve EPSS method could be extended from its traditional use for dichotomous classification of "normal" or "abnormal" to a quantitative prediction of the LVEF as a continuous variable. The major finding in this study is that after excluding several easily identified conditions, a simple regression equation based on the EPSS can provide a useful estimate of the LVEF across the full spectrum of values.

Although the visual estimation of the LVEF has been improved by LV contrast enhancement,⁹ contrast requires additional time and cost, as well as intravenous access, and is not feasible in all cases. This is particularly true in the outpatient setting. Moreover, inter- and intraobserver variabilities remain significant, especially in patients with multiple wall motion abnormalities. Therefore, a simple complementary

Table 2

Regression equations for prediction of the LVEF from mitral valve EPSS according to homogeneity of segmental wall motion scores

SWMS Group	n	MRI LVEF Range (mean \pm SD)	Regression Equation	Correlation Coefficient (r)	SEE
Low SD (0–17.6)	21	12.2–72.4 (55.7 \pm 13.2)	LVEF = 78.9 – 2.7 · EPSS	0.744	9.3
High SD (18–39.2)	21	10.7–63.3 (39 \pm 14.4)	LVEF = 70.6 – 2.3 · EPSS	0.739	9.9

SWMS = segmental wall motion score.

method for estimating the LVEF that is physiologically distinct from the assessment of wall motion scoring may still be useful.

The EPSS is an attractive index of the LVEF because it can be obtained very rapidly, requiring only a single view of the LV base and a single linear distance measurement. Moreover, it is a cumulative marker of function in that it reflects the net effect of wall motion throughout the ventricle, obviating the visualization and assessment of each myocardial segment, and it requires no geometric assumptions about ventricular shape.

The EPSS method can yield misleading results in several conditions, all of which are readily identifiable on the echocardiogram. Conditions that exaggerate the EPSS cause the underestimation of the LVEF and include significant intrinsic mitral valve disease that restricts leaflet motion and aortic insufficiency of at least moderate severity. Conditions that can lead to a factitiously small EPSS and the overestimation of the LVEF include discrete upper septal thickening, asymmetric septal hypertrophy, significant anterior septal curvature at the time of measurement, severe mitral regurgitation, and severe LV hypertrophy. We had to exclude only 11% of patients because of the presence of these conditions. This number would depend on the patient population. It is noteworthy, however, that the heterogeneity of segmental wall motion abnormalities did not affect the correlation between the LVEF estimated by the EPSS and the MRI LVEF, nor did it alter the values of the regression equation coefficients. Thus, the same equation can be used for myopathic disease or in patients with ischemic cardiomyopathy.

Accurate use of the regression equation requires several methodologic precautions. The EPSS can be measured in a variety of views, but the values cannot be expected to agree. It can be seen in the short-axis view of the mitral valve opening that because of the curvature of the anterior leaflet at peak excursion, the distance from leaflet to septum shows a significant angular variation. There is very little separation near the leaflet attachments medially and laterally and maximum separation at the mid-leaflet. Therefore, the angular orientation of the imaging plane can affect the EPSS. Similarly, variation can also occur in the short-axis view, when measured either directly on the 2-dimensional or on the derived M mode, because the cross section may not be at the axial level at which the distance between the leaflet and the septum is at a minimum. Finally, because of the tilt of the LV axis, the ultrasound beam can traverse the left ventricle obliquely and

the EPSS can be distorted in M-mode images. This effect may have contributed to the historical limitation of EPSS to a dichotomous index of function. Reliability is improved by measurement directly from the 2-dimensional image itself, or from a M mode that is guided by the 2-dimensional image. Because of these factors, we believe that the use of our regression equation should be restricted to the same view from which we obtained our data, which corresponded to the standard 2-dimensional parasternal long-axis view optimized for the valvular structures at the LV base, including the aortic valve. Our regression equation may not be reliable in the apical long-axis view or on imaging by transesophageal echocardiography. Another precaution we recommend is to avoid mistaking a mitral valve chord attached near the tip of the anterior leaflet for the leaflet itself when measuring the EPSS. This error is more likely on a M-mode image but still must be guarded against on a 2-dimensional image. We prefer to cycle frame by frame from early mitral valve opening to peak excursion, keeping careful track of the leaflet to avoid this problem.

Our study is limited by the use of cardiac magnetic resonance images to measure the EPSS rather than echocardiographic images themselves. However, we made all our measurements on images that corresponded highly to the standard parasternal long-axis view. Moreover, the use of MRI for the LVEF and the EPSS permitted us to obtain the experimental LVEF and the gold-standard LVEF at identical clinical moments in time. We were therefore able to eliminate the uncertainty that arises from a time lapse between the measurements. The MRI LVEF by Simpson's rule is widely considered the most accurate and most robust method for quantifying the LVEF.^{10,11}

Our results indicate that although the mitral valve EPSS does not provide definitive quantitative values of the LVEF, it represents a simple and rapid method that can be a useful adjunct to routine interpretation of clinical studies. With the precautions noted, the EPSS can yield information on LV function that goes beyond a simple classification into "normal" and "abnormal" categories.

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