Mitral Annular Plane Systolic Excursion as a Surrogate for Left Ventricular Ejection Fraction

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Background: Assessing left ventricular function is a common indication for echocardiography. It generally requires expert echocardiographer estimation and is somewhat subjective and prone to reader discordance. Mitral annular plane systolic excursion (MAPSE) has been suggested as a surrogate measurement for left ventricular function. The aim of this study was to examine the accuracy of MAPSE for predicting left ventricular ejection fraction (EF) on the basis of a large cohort of consecutive echocardiograms.

Methods: The study design was a retrospective analysis of 600 two-dimensional echocardiographic studies performed in a single laboratory. MAPSE measurement was performed by an untrained observer and compared with the EF as determined by an expert echocardiographer. The first 300 studies served as a calibration cohort to establish an algorithm for predicting EF on the basis of MAPSE measurement. The following 300 studies served as a verification cohort to test the accuracy of the established algorithm.

Results: Using the first 300 studies, an algorithm was developed to predict EF. Cutoff values for normal EF ($\geq 11$ mm for women and $\geq 13$ mm for men) and severely reduced EF ($<6$ mm for men and women) were identified. For the intermediate-range MAPSE values, a gender-specific regression equation was calculated to generate a predicted EF. Using this algorithm, predicted EFs were determined for the 300 patients in the verification cohort. By comparing the predicted EF and the expert-reported EF, positive and negative predictive values, sensitivity (73%–92%), specificity (81%–100%), and accuracy (82%–86%) of MAPSE for predicting EF were calculated.

Conclusions: MAPSE measurement by an untrained observer was found to be a highly accurate predictor of EF. (J Am Soc Echocardiogr 2012;25:969-74.)

Keywords: Ejection fraction, MAPSE

Assessing left ventricular systolic function is a common indication for transthoracic echocardiography. Stroke volume determination via echocardiography has been clinically relevant since the 1960s.1 Left ventricular function is often expressed as an assessment of left ventricular ejection fraction (EF), which over time has been determined using numerous methods. Each of these requires an expert physician echocardiographer and is somewhat subjective and prone to reader discordance and variability. Also, assessing left ventricular EF using currently available techniques is highly dependent on adequate endocardial resolution and the technical quality of the echocardiographic study.2

During systole, both longitudinal and circumferential fibers contribute to myocardial contraction. Gibson and colleagues have done extensive work studying the importance of longitudinal fiber shortening and its relationship to left ventricular function. He and others demonstrated that the movement of the mitral annulus toward the apex is a result of long-fiber contraction.3 During diastole, the annulus moves back away from the apex. Left ventricular apical motion is limited throughout the cardiac cycle, such that the distance between the apex of the heart and the chest surface is almost constant during contraction. The magnitude of the displacement of the mitral annulus during myocardial contraction can be measured from M-mode images of the mitral annulus4 (Figure 1).

Mitral annular plane systolic excursion (MAPSE), also referred to as mitral annular motion or atrioventricular displacement, was measured as early as 1967, when Zaky et al.5 described a “curve contour” using M-mode echocardiography through the mitral ring, which measured 1.6 ± 0.4 cm. They found “deviations” from this normal value in the movement of the mitral ring in patients with heart disease. MAPSE more recently has been suggested as a surrogate measurement for left ventricular function.6-8 Some have shown linear correlations between expert-measured EF and MAPSE; one study showed that a MAPSE value of $<7$ mm had sensitivity of 92% and specificity of 67% for detecting severe left ventricular dysfunction. A separate study demonstrated that a MAPSE value of $<12$ mm had 90% sensitivity and 88% specificity for the detection of EF $<50$.9 Others have shown that MAPSE measurements correlate well with other techniques for left ventricular functional assessment, including three-dimensional echocardiography and cardiac magnetic resonance imaging (MRI).10,11 Tsang et al.12 studied the correlation of MAPSE, as derived from

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METHODS

The study design was a retrospective analysis of echocardiograms obtained for clinical indications. Six hundred consecutive two-dimensional (2D) echocardiographic studies done in the echocardiography laboratory at Lenox Hill Hospital (an urban teaching hospital) were included in our study (Philips iE33 xMATRIX Ultrasound System; Philips Medical Systems, Andover, MA). M-mode echocardiography through the mitral valve annulus, from the apical four-chamber view at both the septal and lateral annuli, is routinely performed and recorded in all studies in our laboratory. No specific image orientation was used for the purpose of MAPSE measurement; the images were optimized for routine four-chamber view evaluation. The M-line was positioned through the medial and lateral annulus and included the tissue-blood border for easy identification of the motion of the annulus. The trough of the motion was defined as the end-diastolic position of the annulus, measured at the tip of the QRS complex. The peak was defined as the maximal systolic excursion point. MAPSE measurement was performed by a fourth-year medical student, blinded to the official report of the echocardiogram. The student was initially trained by the attending echocardiographer to accurately measure MAPSE, identifying the required images and the trough and peak of annular motion, and using the calipers on the digitized system. Once the student demonstrated adequate skill at performing these measurements, the student’s independent MAPSE measurements began for the study purpose.

The average MAPSE value (mean of septal and lateral values) was obtained for each patient and used in the analysis. Each study was interpreted (clinically) by an expert echocardiographer, providing an expert estimation of the EF that was based on “eyeballing,” with or without the use of Simpson’s method of disks. Because the purpose of the study was to assess how MAPSE measurement performs relative to an expert interpretation of an echocardiogram, there was no prerequisite requirement for the readers as to how to determine the EF.

Baseline patient characteristics were collected for all studies; these included age, gender, height, weight, body surface area, and the technical quality of the study. Technical quality was graded on a numeric scale (1 = poor, 2 = fair, 3 = good, and 4 = excellent).
RESULTS

Calibration Cohort

Three hundred consecutive 2D echocardiographic studies were reviewed by the medical student, and MAPSE values were measured in all 300 patients. No patients were excluded from data analysis. Data recorded for each patient are listed in Table 1. Of all the patient characteristics documented, gender had the greatest correlation with EF. Although MAPSE values were similar between genders, we found that on average, a given MAPSE value correlated with a higher EF in women. Given this observation, for establishing an algorithm for determining EF from MAPSE, men and women were analyzed separately.

Our initial analysis of the 300 studies in the calibration cohort (in accordance with data from previous research) showed that MAPSE values ≥ 13 mm in men consistently predicted a normal or increased EF. Similarly, we found that in women, MAPSE values ≥ 11 mm consistently predicted a normal or increased EF. Likewise, we found that a MAPSE value < 6 mm (for both men and women) served as an appropriate cutoff for predicting severely depressed EF (≥30%).

Gender-specific scatterplots were constructed to evaluate MAPSE versus EF for those patients who had MAPSE measurements between the previously mentioned cutoff values (Figure 2). A regression line was obtained from each scatterplot; for men, 4.8 × MAPSE (mm) + 5.8 (R = 0.644), and for women, 4.2 × MAPSE (mm) + 20 (R = 0.470).

Given these data, we created an algorithm for predicting EF on the basis of MAPSE measurement. For women, a MAPSE value ≥ 11 mm determined a normal EF (≥55%), while in men, this value was 13 mm. A MAPSE value < 6 mm in either gender was considered to reflect a severely depressed EF (≤30%). A MAPSE measurement between these cutoff values was used in the gender-specific regression equation, and a predicted EF was calculated.

Verification Cohort

Another cohort of 300 consecutive 2D echocardiographic studies was reviewed by the medical student. Baseline patient characteristics, as well as general quantitative and qualitative data for the verification cohort, are listed in Table 2. There were no significant differences between the calibration cohort and the verification cohort. Similarly to the calibration cohort, a difference in average EF between men and women despite lack of difference in average MAPSE was noted in the verification cohort (Table 3). MAPSE values were measured by the medical student, blinded to the expert report. Using this measurement, a predicted EF was determined on the basis of the algorithm established in the calibration cohort.

To determine the accuracy of our algorithm, absolute variation from expert-reported EF was calculated for each patient. If a patient had a MAPSE value < 6 mm and an EF ≤ 30%, this was considered a concordant event. In addition, if a female patient had a MAPSE value ≥ 11 mm or a male patient had a value ≥ 13 mm and the expert-reported EF was normal or increased, this was also considered a concordant event. Concordant events were determined to have variation from expert-reported EFs of zero.

For patients with MAPSE above the normal threshold with expert-reported EFs below normal, variation was calculated by assigning a predicted EF of 60%. For patients with MAPSE values < 6 mm and expert-reported normal EFs, variation was calculated by assigning a predicted EF of 30%.

The accuracy of MAPSE < 6 mm for predicting a severely depressed EF was calculated (Table 4). The positive predictive value was 100% in men and 88% in women. Sensitivity was 73% in men and 100% in women.

The positive predictive value for MAPSE ≥ 11 mm in women to predict a normal EF was 94%. Sensitivity for this cutoff value was 92%. The positive predictive value for MAPSE ≥ 13 mm in men to predict a normal EF was 94%. The sensitivity of this cutoff value was the same as the value for women, 92%.

For each patient in the verification cohort, a ΔEF value was calculated. This was determined by calculating the absolute difference between the expert-reported EF and the algorithm-predicted EF. Eighty-six percent of men and 82% of women had ΔEF values ≤ 7 (i.e., the predicted EF and expert-reported EF differed by ≤7 percentage points). Differences between predicted EFs and expert-reported EFs of ≥5 percentage points were found in 75% of men and 76% of women (Table 4).

Image quality was not statistically different between the calibration and verification cohorts (Table 2). We evaluated separately the group of patients with fair-quality or poor-quality studies to assess the effect of image quality on the accuracy of MAPSE for predicting EF. There was no significant difference between these studies and those with good or excellent quality (Table 4). Eighty-five percent of cases with poor-quality or fair-quality images had ΔEF values ≤ 7 percentage points. Seventy-four percent of cases had ΔEF values ≤ 5 percentage points. This demonstrates that student-measured MAPSE is capable of predicting EF regardless of the image quality of the study.

The interobserver variability in the MAPSE measurement was 9.5 ± 8.1%, and the intraobserver variability was 9.3 ± 6.9%.

Table 1 Baseline characteristics for the initial 300 patients (calibration cohort)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cohort (n = 300)</th>
<th>Men (n = 147)</th>
<th>Women (n = 153)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>65.9 ± 17.4</td>
<td>63.2 ± 15.6</td>
<td>68.1 ± 18.8</td>
<td>.015</td>
</tr>
<tr>
<td>Age range (y)</td>
<td>18–100</td>
<td>20–100</td>
<td>18–100</td>
<td>—</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.86 ± .29</td>
<td>2.02 ± .26</td>
<td>1.71 ± .22</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Average MAPSE (mm)</td>
<td>10.9 ± 3.0</td>
<td>10.7 ± 3.4</td>
<td>10.9 ± 2.7</td>
<td>.53</td>
</tr>
<tr>
<td>Reported EF (%)</td>
<td>56.8 ± 13.4</td>
<td>53 ± 15</td>
<td>60 ± 10</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Average image quality*</td>
<td>2.82 ± 0.54</td>
<td>2.88 ± 0.60</td>
<td>2.80 ± 0.52</td>
<td>.223</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. Men and women were analyzed separately given our observation that for a given MAPSE value, men had lower EFs than women.

*Image quality was graded on four-point scale (1 = poor, 2 = fair, 3 = good, and 4 = excellent).

DISCUSSION

Our results demonstrate that MAPSE values, measured by an untrained reader, are accurate predictors of left ventricular EF. We verified this in a large cohort of consecutive patients (600) with no exclusion criteria, representative of what might be seen in any busy echocardiography laboratory. This is the largest study thus far to correlate MAPSE and EF.

We created a simple algorithm for the prediction of EF on the basis of MAPSE values; high and low cutoff values were defined to help quickly determine normal and severely reduced EF. For MAPSE...
Predicted EF on the basis of MAPSE as 4.2 × MAPSE (mm) + 5.8. (Left) Data for men show an R value of 0.644. Regression analysis provided a formula for calculating predicted EF on the basis of MAPSE as 4.8 × MAPSE (mm) + 5.8. (Right) Data for women show an R value of 0.470. Regression analysis provided a formula for calculating predicted EF on the basis of MAPSE as 4.2 × MAPSE (mm) + 20.

Values between these cutoff numbers, gender-specific linear equations were established.

MAPSE is a simple M-mode measurement that is almost independent of image quality for its accuracy. This was demonstrated in our study: poor image quality had no effect on the accuracy or precision of our measurements. Thus, measuring MAPSE may become an alternative way to assess left ventricular function if the echocardiographic study is performed during off hours by less experienced individuals (e.g., on-call house officers) and there is no expert reader immediately available for consultation.

All MAPSE measurements done in this study were performed by a medical student with no prior training in echocardiography. The student was blinded to all echocardiographic reports until after MAPSE measurements had been performed. Estimating EF via eye-balling is an imperfect science that can take years to master. A student was blinded to all echocardiographic reports until after the preliminary result, to be followed by a complete expert evaluation of the echocardiogram.

A new finding noted in our calibration and verification cohorts was the difference in MAPSE values between men and women. In both cohorts, we found that although average MAPSE values did not differ significantly between men and women, EFs did. For a given MAPSE value, the correlating EF was higher for women than for men. Otherwise stated, for a given EF, women had lower MAPSE values than men. No study to date has been published that evaluated gender differences specifically as a factor that affects the correlation between MAPSE and EF. Prior work suggested a gender difference in EF in the general population as well as in patients with certain heart conditions, for example, aortic stenosis. Villari et al. found that for a similar degree of aortic stenosis, women had higher EFs than men, while myocardial stiffness constant was found to be higher in men than women. In addition, previous work has shown that a larger heart size correlates with a larger MAPSE for a given EF. Because women’s hearts are typically smaller than men’s, the mitral annulus has a shorter distance to travel toward the apex during systolic motion. This could account (at least partially) for the observed differences between men and women.

### Table 2 Comparison of calibration and verification cohorts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Training cohort (n = 300)</th>
<th>Verification cohort (n = 300)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>65.87 ± 17.4</td>
<td>63.86 ± 17.17</td>
<td>.098</td>
</tr>
<tr>
<td>Age range (y)</td>
<td>18–100</td>
<td>22–94</td>
<td>—</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.86 ± .29</td>
<td>1.89 ± .27</td>
<td>.15</td>
</tr>
<tr>
<td>Average MAPSE (mm)</td>
<td>10.9 ± 3.0</td>
<td>11.3 ± 3.06</td>
<td>.051</td>
</tr>
<tr>
<td>Reported EF (%)</td>
<td>56.8 ± 13.4</td>
<td>56.47 ± 13.08</td>
<td>.378</td>
</tr>
<tr>
<td>Average image quality*</td>
<td>2.82 ± .54</td>
<td>2.82 ± .53</td>
<td>.316</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. Comparison of baseline characteristics of both patient cohorts was performed to ensure consistency between the two 300-patient groups. As shown, none of these characteristics showed a statistically significant difference.

*Image quality was graded on four-point scale (1 = poor, 2 = fair, 3 = good, and 4 = excellent).

### Table 3 Gender differences in MAPSE and EF in the verification cohort

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (n = 159)</th>
<th>Women (n = 141)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average MAPSE (mm)</td>
<td>11.4 ± 3.1</td>
<td>11.4 ± 3.1</td>
<td>.33</td>
</tr>
<tr>
<td>Reported EF (%)</td>
<td>54 ± 14</td>
<td>59 ± 12</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. Verification cohort data separated by gender; for a given MAPSE value, men had lower EFs than women. No significant difference between MAPSE values of men and women was seen, but men had significantly lower EFs (P < .001).
women and explain why the threshold for a normal MAPSE for women should be lower than that of men.

MAPSE, in addition to being a simple surrogate for EF, may have additional implications for patient outcomes. Willenheimer et al. demonstrated that among patients with heart failure, those with decreased MAPSE levels had significantly higher mortality. Previous work done on tricuspid annular systolic excursion has also shown that a simple one-dimensional measurement can predict mortality in patients with heart failure. MAPSE may also detect pathology other than a depressed EF. Wenzelburger et al. demonstrated that MAPSE values are decreased in patients with heart failure with preserved EF versus normal controls.

Future work should be done in large patient populations to assess the correlation between serial MAPSE measurements and patient outcomes. A decrease in MAPSE may be a predictor of heart pathology and may aid in patients’ risk stratification by an easily measured, bedside echocardiographic parameter.

Limitations

We examined the accuracy of student-measured MAPSE for predicting left ventricular EF. We compared the MAPSE-predicted EF with 2D-based expert-reported EF. We did not compare MAPSE with a non-echocardiography-based technique (i.e., cardiac MRI). Because our study sample was so large, it was not feasible to perform an extra imaging modality in all patients included. Although visual estimation of EF may be subjective and prone to error, previous studies have shown that when performed by experienced echocardiographers, it is quite accurate compared with other techniques. Furthermore, the goal of our study was to define a simple echocardiographic method that can be used (even by inexperienced observers) for a quick estimation of global EF, not to replace other, more sophisticated techniques.

We did not attempt to examine the effect of specific disease entities on MAPSE measurements. For example, localized wall motion abnormalities due to coronary artery disease, significant mitral annular calcifications, prosthetic valves, and more can definitely affect MAPSE values, irrespective of global EF. Although assessing all these issues is an important task of echocardiography, often there is urgent clinical need to obtain assessment of global EF to guide acute management decisions. As such, MAPSE may be very helpful in urgent, off-hours clinical decision making.

CONCLUSIONS

Our work has determined that MAPSE, measured by an untrained observer, is a viable surrogate for expert determined left ventricular EF. Our findings suggest that gender significantly affects this correlation. We have established upper and lower thresholds for normal and severely reduced EFs for each gender and a simple gender-specific equation to calculate EF from intermediate MAPSE values. We believe that MAPSE should be routinely acquired in all echocardiographic studies and used as a surrogate for global left ventricular EF.

REFERENCES