Prediction of Successful Outcome in 130 Patients Undergoing Percutaneous Balloon Mitral Valvotomy

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We studied 130 patients undergoing percutaneous balloon mitral valvotomy. The relation between valvular morphology according to a previously described echocardiographic scoring system and hemodynamic outcome expressed as qualitative (“good” and suboptimal) and as absolute change in valve area was analyzed. The relative importance of the individual components of this echocardiographic score (valvular thickening, mobility, calcification, and subvalvular disease) to the change in valve area after valvotomy was also examined. Mean transmitral pressure gradient decreased from 16±6 to 6±3 mm Hg (p<0.0001), and mitral valve area increased from 0.9±0.3 to 1.8±0.7 cm² (p<0.0001). Results in individual patients were variable. Eighty-four percent (61 of 73) of patients with an echocardiographic score of 8 or less had a “good” outcome (final valve area ≥1.5 cm² and an increase in valve area of ≥25%), whereas 58% (33 of 57) of patients with an echocardiographic score of 8 or more had a suboptimal result (p<0.001). The sensitivity of an echocardiographic score of 8 or less for predicting a “good” outcome was 72%, and the specificity was 73%. The echocardiographic score correlated negatively (r=−0.40, p<0.0001) with the absolute increase in mitral valve area after valvotomy, but there was substantial scatter in the data. Of the four components of the total echocardiographic score, varvular thickening correlated best with the absolute change in valve area (r=−0.47, p<0.0001). Multiple regression analysis selected valveular thickening as the only morphological predictor of the change in valve area, followed by a larger effective balloon dilating area and sinus rhythm. The equation derived from this multivariate analysis was used to predict the absolute change in valve area after valvotomy. Although the predicted and the observed change in valve area correlated significantly (r=0.56, p<0.0001), there was substantial scatter in the data. (Circulation 1990;82:448–456)

We have previously reported that an echocardiographic score of valve morphology predicted immediate outcome after percutaneous mitral valvotomy in an initial group of 22 patients.¹ This initial impression was confirmed in a larger group of 100 patients in a more recent study from our institution.² In addition to exerting an influence on immediate outcome, mitral morphology assessed by echocardiography was also found to influence longer-term outcome in a subgroup of patients observed for several months. In both of these studies, outcome after valvotomy was expressed only as a binary quantity, that is, optimal versus suboptimal. Furthermore, the relative importance of the individual components of the echocardiographic score, valvular thickening, mobility, calcification, and subvalvular disease, and their relation to outcome were not examined.

The purposes of this study were to examine 1) whether the relation between the echocardiographic score of valve morphology and immediate outcome

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remains significant in a larger group of patients after percutaneous balloon mitral valvotomy, 2) whether the echocardiographic score is useful for predicting the absolute change in valve area after this procedure, 3) whether the value of the echocardiographic score can be improved by varying the relative weight of its individual components, and 4) whether the inclusion of a combination of clinical factors other than morphology may better predict outcome.

**Methods**

**Study Population**

We studied 130 consecutive patients with mitral stenosis who underwent percutaneous balloon mitral valvotomy at our institution from November 1985 to January 1988. Data for the first 22 patients were analyzed retrospectively, and the results were previously reported. The remaining data were gathered prospectively. There were 107 women and 23 men, and their mean age was 55±17 years (range, 14–87 years). There were 71 patients in sinus rhythm and 59 in atrial fibrillation. Thirty-one patients were in New York Heart Association (NYHA) functional class IV, 80 in class III, 18 in class II, and one patient in class I. (This one patient in NYHA class I underwent prophylactic balloon valvotomy because of an anatomical decrease in valve area and her desire to become pregnant.)

**Study Protocol**

**Hemodynamics.** All patients underwent percutaneous mitral balloon valvotomy by the transseptal approach. Before and after valvotomy, left and right heart pressures were obtained, and cardiac output was measured with the thermodilution method. The Fick method was used when tricuspid regurgitation or an atrial septal defect was detected. Mitral valve area was calculated with the Gorlin formula. The single-balloon technique was performed in 28 patients, and the double-balloon technique was performed in 102 patients. Effective balloon dilating area (EBDA) was calculated by assuming continuity of the circumference surrounding the two separate balloons. Mitral regurgitation was evaluated with cine left ventriculography, and its severity was graded from 1+ to 4+ as described previously. Mitral valve calcification was assessed by fluoroscopic examination at the time of catheterization, and its severity was graded from 0 to 4+ as previously described.

**Echocardiographic examination.** Before percutaneous mitral valvotomy, a complete two-dimensional echocardiographic study was performed in all patients with either a Hewlett-Packard 77020A ultrasound imager equipped with a 2.5-MHz phased-array transducer or an ATL MK 600 ultrasound imager equipped with a 3.0-MHz mechanical transducer. Standard echocardiographic images were obtained in the parasternal long- and short-axis views and the apical four-chamber and long-axis views. Special attention was taken to image the subvalvular apparatus in its entirety with modified parasternal long-axis and apical four-chamber and long-axis views. All two-dimensional echocardiographic images were recorded on ½-in. videotape for further analysis.

**Data Analysis**

A previously described semiquantitative echocardiographic assessment of mitral valve morphology (score) was obtained in each patient by assigning a severity grade from 0 to 4 to each of the following valvular morphological and functional characteristics: valvular mobility, thickening, calcification, and subvalvular disease. Higher values represented greater morphological abnormality. A total echocardiographic score was obtained for each patient by adding the severity grades for the individual features listed above. The total echocardiographic score therefore could range from 0 to 16. However, because all patients with mitral stenosis by definition have some degree of valvular thickening and restriction in mobility, the actual range extended from 2 to 16.

To assess the relation between the echocardiographic score of valve morphology and immediate outcome, patients were arbitrarily divided into two groups: Those with a post-valvotomy mitral valve area of 1.5 cm² or more and an increase in valve area of at least 25% were classified as the “good” result group, and those who failed to meet these criteria were considered to have a suboptimal outcome. These criteria were selected before data analysis and were based on the following considerations. Patients with mitral stenosis and valve areas of 1.5 cm² or more are generally considered to have mild stenosis and to be relatively asymptomatic from their disease; therefore, such value was chosen as the threshold area. In a previous study from this institution that described the results of the first 22 patients undergoing balloon mitral valvotomy, a threshold valve area of 1.0 cm² was used to describe a “good” outcome. In that early experience, most patients were critically ill; therefore, a postprocedure valve area of 1.0 cm² or more was considered a “good” result. As our experience increased, patients with less severe mitral stenosis underwent the procedure, including some with valve areas greater than 1.0 cm² before valvotomy. This necessitated a change in the absolute valve area that could be considered an optimal result. The new threshold area was also used in a subsequent study from this institution.

An increase in valve area after valvotomy of 25% or more was chosen as a second requirement because there were patients with valve areas close to 1.5 cm² before valvotomy. Without this requirement, an increase in valve area of only 0.1 cm² (i.e., 1.4 to 1.5 cm²) in these patients could have led to classification as a “good” result. The figure of 25% was chosen because it was considered a reasonable increase that would be outside the range of error for sequentially acquired data in the same patient.


Statistical Methods

Measurements before and after mitral valvotomy were compared by the Student's paired t test. Comparisons between the "good" and suboptimal result groups were made with the unpaired Student's t test.

The sensitivity of the total echocardiographic score for predicting a "good" outcome was calculated for each echocardiographic score value as the proportion of all patients with a "good" outcome who had scores equal to or less than that score value. The specificity was the proportion of all patients with a suboptimal outcome who had a total echocardiographic score above that score value.

Linear regression analysis was used to examine the relation between the morphological and functional characteristics of mitral valve morphology and the absolute change in mitral valve area after valvotomy. The total echocardiographic score and its four components, valvular mobility, thickening, calcification, and subvalvular disease were examined. The correlation coefficients derived from these relations were compared by Fisher's z transformation. In addition, demographic and hemodynamic variables were examined with multiple regression analysis to determine whether there were other factors predictive of immediate results. The variables examined were age, sex, cardiac rhythm, NYHA functional class, EBD, calcification by fluoroscopy, and the following parameters measured before valvotomy, namely, severity of mitral regurgitation, mitral transvalvular gradient, cardiac output, mitral valve area, and mean pulmonary artery pressure.

Results were expressed as mean±SD. Results were considered significant when p<0.05 for univariate statistics. The Bonferroni correction was used to account for multiple comparisons, and a p value less than 0.003 was considered significant.

Hemodynamics

Mitral valve area increased from 0.9±0.3 before to 1.8±0.7 cm² (p<0.0001) after valvotomy. Mean mitral valve pressure gradient decreased from 16±6 to 6±3 mm Hg (p<0.0001), mean left atrial pressure decreased from 24±7 to 14±5 mm Hg (p<0.0001), mean pulmonary artery pressure decreased from 40±13 to 29±10 mm Hg (p<0.0001), and cardiac output increased from 3.8±1.0 to 4.4±1.1 l/min (p<0.0001) after the procedure.

Although valve area increased in most patients after percutaneous mitral valvotomy, changes in individual patients were variable. Using the criteria for outcome described previously, we noted that there were 85 (65%) patients with a "good" and 45 (35%) with a suboptimal outcome.

Cine left ventriculography was performed before and after valvotomy in 118 patients to assess mitral regurgitation. Before valvotomy, 83 patients had no mitral regurgitation, 32 had 1+ and three had 2+ mitral regurgitation. No patient had 3+ or 4+ regurgitation. Immediately after valvotomy, 45 patients had no mitral regurgitation, 47 had 1+, 18 had 2+, seven had 3+, and 1 had 4+ mitral regurgitation. Mitral regurgitation did not change in 61 (52%) patients, increased by 1+ in 42 (36%) patients, by 2+ in 12 (10%) patients, and by 3+ in 2 (1.6%) patients. In one patient, mitral regurgitation decreased from 2+ to 1+ immediately after valvotomy.

Results

Bar graph of number of patients with "good" and suboptimal outcome for each echocardiographic score. All patients with low echocardiographic scores (4 and 5) had optimal outcome. Number of patients with good outcomes decreases as the echocardiographic score increases.

Figure 1. Bar graph of number of patients with "good" and suboptimal outcome for each echocardiographic score. All patients with low echocardiographic scores (4 and 5) had optimal outcome. Number of patients with good outcomes decreases as the echocardiographic score increases.

Figure 2. Plot of sensitivity and specificity of the echocardiographic score for predicting a "good" outcome. Sensitivity increases and the specificity decreases as the echocardiographic score increases. Optimal combination of sensitivity and specificity occurs at an echocardiographic score of 8.

Table 1. Sensitivity, Specificity, and Positive and Negative Predictive Value for an Echocardiographic Score of 8 or Less

<table>
<thead>
<tr>
<th>Echocardiographic score</th>
<th>Good</th>
<th>Suboptimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤8</td>
<td>61</td>
<td>12</td>
</tr>
<tr>
<td>&gt;8</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td>45</td>
</tr>
</tbody>
</table>

Sensitivity 72%
Specificity 73%
+Predictive value 84%
−Predictive value 58%

Good, final mitral valve area ≥ 1.5 cm² and 25% increase in mitral valve area.
Echocardiography

Relation of valve morphology to outcome. Total echocardiographic scores were significantly lower in the group of patients with a "good" outcome compared with those with a suboptimal outcome (7.3±2.1 versus 10.0±2.3, p<0.0001).

Figure 1 shows the number of patients with "good" and suboptimal results stratified according to total echocardiographic score. All patients with very low echocardiographic scores (4 and 5) had a "good" outcome, and the proportion of patients with "good" outcome decreased progressively with increasing echocardiographic score. The number of patients studied with high echocardiographic score (≥12) was small (11 of 130 patients); however, a subgroup of these patients had a "good" outcome despite a more severe degree of morphological impairment.

The sensitivity and specificity of the total echocardiographic score for predicting a "good" outcome are shown in Figure 2. Sensitivity increased and the specificity decreased as the echocardiographic score increased. The optimal combination of sensitivity and specificity as defined by the cross-over point of the two curves occurred at an echocardiographic score of 8. Sensitivity, specificity, and positive and negative predictive values with an echocardiographic score of 8 and less were calculated (Table 1). Most patients with an echocardiographic score of 8 or less (61 of 73 patients, 84%) had a "good" result, whereas most of those with scores greater than 8 (33 of 57 patients, 58%) had a suboptimal outcome. The sensitivity of a score of 8 or less for predicting a "good" outcome was 72% and the specificity 73%. The corresponding positive predictive value was 84% and the negative predictive value was 58%.

Relation of valve morphology to absolute change in valve area. In addition to the binary classification of patients into "good" and suboptimal outcome, the relation between the echocardiographic score and the absolute change in valve area after valvotomy was also examined (Figure 3). Although there was a significant negative correlation between the absolute change in valve area and the total echocardiographic score (r=−0.40, p<0.0001, sdr=0.54), there was substantial scatter in the data (Figure 3).

To reassess the relative role of the echocardiographic score in predicting the absolute increase in mitral valve area after valvotomy in this larger group of patients, multiple linear regression analysis was used to examine the relation between the absolute change in valve area and the various hemodynamic, demographic, and morphological aspects of the mitral valve. Of these factors, the echocardiographic score was the most significant univariate predictor (p<0.0001) (Table 2) followed by the effective balloon dilating area (p<0.0007). Cardiac rhythm (atrial fibrillation) (p<0.005), age (p<0.009), and calcification according to fluoroscopy (p<0.018) tended toward, but did not reach, the significance level of p<0.003 deemed significant after Bonferroni correction.

When the individual components of the echocardiographic score were cross correlated, significant relations were uniformly found, indicating that abnormalities in these characteristics tended to progress together in the same patient (Table 3). To test whether any of these components yielded a better relation with the absolute change in mitral valve area after valvotomy than the total echocardiographic score, the relation of each of these components was assessed with simple linear regression analysis (Figure 4). A clear relationship was seen with each of these components (p<0.0001 for each regression).

![Figure 3](image-url) 

**Figure 3.** Plot of relation between the echocardiographic score and the absolute change in valve area after mitral valvotomy. Although there is a significant correlation (r=−0.40, p<0.0001), the data are substantially scattered.

**Table 2. Univariate Significant Predictors of the Absolute Increase in Mitral Valve Area**

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>−0.22</td>
<td>0.009</td>
</tr>
<tr>
<td>EBDA</td>
<td>0.34</td>
<td>0.0007</td>
</tr>
<tr>
<td>Calcification (fluoroscopy)</td>
<td>−0.20</td>
<td>0.018</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>−0.24</td>
<td>0.005</td>
</tr>
<tr>
<td>Echocardiographic score</td>
<td>−0.40</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

EBDA, effective balloon dilating area.
but significant scatter of individual data was again present.

Of these components, valvular thickening had the highest correlation with the change in valve area \( r = -0.47 \) followed by subvalvular disease \( r = -0.37 \), whereas valvular mobility and calcification had the lowest correlation \( r = -0.29; r = -0.22 \), respectively \( (r_{=0.0001}) \) (Figure 4). Although the correlation coefficient for valvular thickening was higher than that for the total echocardiographic score, there was no statistically significant difference between these two values.

Stepwise multiple regression analysis was performed to identify which of the four components of the echocardiographic score were significant predictors of the absolute change in valve area. Valvular thickening was selected as the only important factor \( r = -0.47 \).

Relation of valve morphology combined with other demographic and hemodynamic parameters to the absolute change in valve area. Because the regression model using valve thickening demonstrated significant scatter of data, a combination of factors in addition to valve morphology was included in the multiple regression to determine whether the change in valve area could be predicted more accurately. This analysis identified valvular thickening, effective balloon dilating area, and rhythm as the most important predictors of the change in mitral valve area after valvotomy, with lower severity grade for thickening, a larger balloon dilating area, and sinus rhythm being favorable characteristics. The regression equation developed from these variables (change in valve area = 0.12 · EBDA−0.23·rhythm−0.27·valvular

<table>
<thead>
<tr>
<th></th>
<th>Mobility</th>
<th>Thickening</th>
<th>Calcification</th>
<th>Subvalvular disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>1</td>
<td>0.64</td>
<td>0.49</td>
<td>0.66</td>
</tr>
<tr>
<td>Thickening</td>
<td>0.64</td>
<td>1</td>
<td>0.54</td>
<td>0.66</td>
</tr>
<tr>
<td>Calcification</td>
<td>0.49</td>
<td>0.54</td>
<td>1</td>
<td>0.52</td>
</tr>
<tr>
<td>Subvalvular disease</td>
<td>0.66</td>
<td>0.66</td>
<td>0.52</td>
<td>1</td>
</tr>
</tbody>
</table>
thickening + 0.89) was then used to predict an absolute change in valve area. Figure 5 shows the relation between the predicted and the observed changes in valve area after valvotomy. It demonstrates that although the correlation coefficient improves compared with the use of the valvular thickening alone, there is still substantial data scatter so that application of the regression model in an individual patient results in considerable variance between the predicted and the observed value. All patients with valve areas of more than 1.4 cm² had a change in valve area greater than predicted. We were unable to detect any demographic, hemodynamic, or echocardiographic factor that could explain the difference between the predicted and observed change in valve area in this subgroup of patients.

Discussion

Percutaneous mitral valvotomy has become established as a nonsurgical alternative for the treatment of mitral stenosis. Although most patients benefit immediately from this procedure, results in individual patients are variable. Therefore, it remains of clinical importance to be able to detect factors that may identify patients who are likely to benefit most from this procedure. We and others have previously demonstrated that the morphological characteristics of the mitral valve and subvalvular apparatus as assessed by two-dimensional echocardiography influence the immediate results after percutaneous balloon mitral valvotomy. These observations agree with surgical data that indicate that patients with pliable valves and absence of calcification have better initial results and long-term prognosis after closed commissurotomy.

In our previous report, the extent and severity of morphological abnormality was expressed semiquantitatively with an echocardiographic scoring system that consisted of four morphological and functional components (valvular thickening, mobility, calcification, and subvalvular thickening). The four components were each assigned a value from 0 to 4 with increasing values representing a greater degree of abnormality. The individual values were then summed to produce a total echocardiographic score. A clear relation was noted between the total echocardiographic score and outcome expressed as either a “good” or a suboptimal result. However, the number of patients studied was small, and to define the relative influence of individual echocardiographic parameters on outcome was not possible. Therefore, it appeared reasonable to reexamine these relations in a much larger patient group in whom the effects of the total score and its individual morphological and functional components could be assessed both as they related to outcome expressed in a binary fashion as “good” or suboptimal and also continuously in relation to the absolute change in valve area. As demonstrated in Table 3, these abnormal morphological characteristics tend to progress together in the same patient so that any potential difference in the relative importance of each characteristic to outcome cannot be easily distinguished unless large numbers of patients are studied. A comparative study of this sort has not previously been reported.

Echocardiographic Score as a Predictor of “Good” Versus Suboptimal Outcome After Valvotomy

In the first of the two methods chosen to analyze the immediate results of valvotomy, we arbitrarily defined “good” and suboptimal results in a binary fashion based on an increase in valve area of 25% or more and a final valve area of 1.5 cm² or more. By this definition, only 65% of patients had a good outcome. Although this figure may seem relatively low, success rate obviously depends on the definition of “good” outcome. Indeed, most patients (97%) who underwent the procedure had some increase in valve area including many in the suboptimal group. When outcome was plotted in relation to the echocardiographic score, it was observed that a score of 8 yielded the optimal combination of sensitivity and specificity for predicting a “good” outcome. Below this level, the sensitivity decreased and specificity increased so that 100% of patients with echocardiographic scores of 5 or less had a “good” outcome (Figure 2). Although most patients (58%) with an echocardiographic score greater than 8 had a suboptimal outcome, one subgroup of patients still benefited from the procedure. Thus, although the percentage of patients with a suboptimal outcome increases as the echocardiographic score increases, a high echocardiographic score does not preclude the possibility of a good result.

Relation Between the Echocardiographic Score and the Absolute Change in Valve Area After Valvotomy

When the echocardiographic score was compared with the absolute change in valve area rather than simply as “good” or suboptimal outcome, a signifi-
cant negative correlation was found. Although these results confirm the influence of valvular and subvalvular morphology and function on intermediate outcome, the correlation coefficient was only fair, and the scatter of individual data points was large. Examination of Figure 3 reveals this scatter to be largest in those patients with intermediate echocardiographic scores. Differences were much more evident among the patients with scores of 4 or 5 and those with scores of 11 or higher.

We therefore examined the relation between other demographic and hemodynamic variables and the absolute change in valve area. Effective balloon dilating area was found to be a significant univariate correlate of the change in valve area after valvotomy but was weaker than the echocardiographic score. Cardiac rhythm, age, and valvular calcification according to fluoroscopy showed a trend toward significance.

Relation Between the Individual Components of the Echocardiographic Score and the Absolute Change in Mitral Valve Area After Valvotomy

Because the echocardiographic score was the strongest predictor of outcome but yielded a relatively weak correlation with the absolute change in valve area, we examined the echocardiographic score itself to see whether its value could be improved. In developing the echocardiographic score, the morphological components were weighted equally to form the total score despite their difference in location or nature (e.g., leaflet versus chordal position or valvular mobility versus valvular thickening). We postulated therefore that these components might not have the same effect on the outcome of the procedure, and therefore, differential weighting of individual components could result in a more predictive scoring system.

Of the four morphological components of the echocardiographic score, valve thickening correlated more closely with the change in valve area than the other three parameters, although all of them were significant univariate correlates. Differences in the correlation coefficients between the components were relatively minor. Examination of the individual data points in Figure 4 demonstrated that when the results of the procedure were analyzed as a continuous variable there was considerable scatter of individual points for each of the four score components, similar to that found for the total score. The spread and overlap of data points were relatively large in those patients with intermediate individual scores of 2 and 3, and group differences could be best appreciated when comparing those with individual scores of 1 and 4. Multiple linear regression analysis of the four individual components of the echocardiographic score identified valvular thickening as the most important predictor of the increase in valve area. The prediction of change in valve area with 125 this multivariate model was modest \( r=0.47 \), and so other demographic and hemodynamic factors were included in a subsequent multivariate analysis.

Multivariate Predictors of Absolute Increase in Mitral Valve Area After Valvotomy

When stepwise multiple regression analysis was applied to account for the interaction of other factors, valvular thickening was selected as the most significant predictor of the change in mitral valve area, followed by effective balloon dilating area and sinus rhythm. The other three components of the score and the total score itself were not chosen, suggesting that in this analysis they did not contribute additional information to that already provided by valvular thickening.

The prediction of the multivariate model is summarized in the graph comparing the predicted with the observed changes in valve area (Figure 5). It is interesting to note that while points falling below an observed value of 1.4 cm\(^2\) are equally distributed around the line of identity, those values of 1.4 cm\(^2\) or more fell almost entirely below the line (Figure 5), indicating a consistent underestimation by the model of results in that range. Thus, patients with the greatest increase in valve area had better results than were predicted from the regression model. This is a positive finding in the sense that a subgroup of patients will do better than predicted from the best available multiple regression model but a disappointing one if the goal is to predict accurately the absolute change in valve area after the procedure. Our data suggest that whether available factors are used singly or in combination our ability is still limited in predicting the increase in valve area after valvotomy. We have been unable to identify from our data an obvious explanation for this finding beyond simply biological variability.

Mitral Regurgitation

Mitral regurgitation is a recognized complication after closed surgical commissurotomy, and it has been reported to occur in 8–20% of such cases.\(^{11,14,15}\) It is also a potential complication after balloon dilatation of the valve and has been reported by others to occur in 25–32% of patients after the procedure.\(^{16–18}\) In this study, mitral regurgitation did not change in approximately half of the patients studied, increased by 1+ in one third of patients, and by more than 2+ in only 12% of patients studied. Of interest, mitral regurgitation decreased by 1+ in one patient.

The presence of mitral regurgitation can lead to an underestimation of the true mitral valve area, because the Gorlin formula requires knowledge of transmorial flow and the thermodilution technique measures only net forward flow, which is lower than transmorial flow in the presence of mitral regurgitation. In this series, only 0.8% of patients before and 22% of patients after valvotomy had a score of 2+ or higher for mitral regurgitation. We divided the 118 patients with cineventriculography into those with and without an increase in mitral regurgitation after valvotomy, and we found no significant difference in the change in
valve area between the two groups (0.97±0.58 cm², 0.81±0.59 cm², respectively, p=NS).

We also examined the relation between the absolute increase in mitral valve area and the echocardiographic score in those patients without and in those with an increase in mitral regurgitation after the procedure. There was a significant correlation in both cases \( r = -0.42, p<0.0001; r = -0.34, p<0.0001 \), respectively with no significant difference between the two \( r \) values.

**Limitations**

The echocardiographic score of valve morphology used in this study was graded subjectively and was semiquantitative in nature. This method of evaluation was adopted because it is relatively simple and does not require tedious measurements, advantages that should facilitate widespread clinical application. We have previously reported that the interobserver and intraobserver variability of these measurements is acceptably low.\(^1\) Although the mitral and subvalvular apparatus are three-dimensional structures, we are forced to evaluate the abnormalities of these structures in two dimensions. Therefore, we might have underestimated some morphological abnormalities even though orthogonal and multiple views were used in the examination. In a preliminary study,\(^1\) the echocardiographic score was validated against pathological specimens (postmortem). The highest correlations occurred between pathological and echocardiographic assessment of valvular thickening, mobility, and calcification, whereas the lowest correlations were found between the pathological and echocardiographic assessment of subvalvular disease.

In this study, there were relatively few patients with very high echocardiographic scores (e.g., greater than 12). This series represented the first 130 mitral valvotomies performed in our institution. Initially, patients undergoing this procedure tended to be critically ill and had more severe valvular involvement. As our experience increased, patients with a wide spectrum of morphological disease underwent balloon dilatation. Toward the end of this series, based on our preliminary reports,\(^1,\)\(^2\) there was increasing reluctance to recommend this procedure in patients with the most severe morphological abnormalities, unless there were overriding clinical circumstances. However, despite the relatively small number of patients in each group with very high scores, a consistent trend in the results was seen across the various groups. Separate analysis of patients with high and low scores demonstrated corroborative results.

The criteria for defining good and suboptimal outcomes were selected arbitrarily. Such an arbitrary approach was unavoidable for a binomial form of analysis, which artificially divided a continuous range of results into two discrete groups. It was because of the recognized limitations of this arbitrary definition that the continuous variable, absolute change in valve area, was also examined.

**Conclusion**

We conclude from this study that in general percutaneous balloon mitral valvotomy produces a beneficial increase in mitral valve area. However, results vary in individual patients. An echocardiographic score of valve morphology is useful in separating patients that are more likely to have a good outcome from those who had a suboptimal result. Of the individual morphological components, valve thickening correlates best with the absolute change in valve area. Attempts to predict an absolute change in valve area however yielded relatively modest correlations even with the inclusion of factors other than valve morphology in the regression model.

Thus, although echocardiographic morphology significantly influences immediate outcome, the increase in valve area after percutaneous mitral valvotomy results from a complex and as yet poorly understood interplay of other factors. Echocardiographic morphology of the mitral apparatus may be used to guide the indications for percutaneous mitral valvotomy, but at the present time, the final decision to perform the procedure in an individual patient has to be based on other clinical considerations as well. It is envisaged that with the future application of such echocardiographic information in selecting patients for valvotomy, and perhaps with further improvements in our ability to identify patients who are suitable for the procedure, the proportion of patients with good results will be substantially increased.

We continue to use the total echocardiographic score for evaluating mitral morphology in patients undergoing balloon valvotomy, even though correlation coefficients relating the echocardiographic score and valvular thickening to the change in valve area were similar. This method of grading is still relatively new and remains under continual evaluation. Recent studies evaluating the long-term follow-up of these patients have suggested that the echocardiographic score may be an important factor in predicting restenosis,\(^2,\)\(^5\) and the influence of the individual components of the echocardiographic score on the long-term results of mitral valvotomy has not been examined.

**References**

5. Herrmann HC, Wilkins GT, Abascal VM, Weyman AE, Block PC, Palacios IF: Percutaneous balloon mitral valvotomy for

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V M Abascal, G T Wilkins, J P O'Shea, C Y Choong, I F Palacios, J D Thomas, E Rosas, J B Newell, P C Block and A E Weyman

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