Emergent Balloon Mitral Valvotomy in Patients Presenting With Cardiac Arrest, Cardiogenic Shock or Refractory Pulmonary Edema

YASH Y. LOKHANDBALA, MD, DARSHAN BANKER, MD, AMIT M. VORA, PRAFULLA G. KERKAR, MD, JAYA R. DESHPANDE, MD*, HEMA L. KULKARNI, MD, BHARAT V. DALVI, MD, FACC

Mumbai, India

Rheumatic heart disease (RHD) is a major cardiac problem in India. Patients often remain untreated until a very advanced stage because of poverty, ignorance and an inadequate primary health care infrastructure. In India 6 million children are affected by RHD, and 25% of them have mitral stenosis (MS) (1). Many of these patients present in a critically ill condition. Unlike patients with end-stage myocardial dysfunction in valvular regurgitant lesions, patients with MS and significant cardiovascular compromise can lead a productive life, if the stenosis is relieved.

Since its introduction by Inoue et al. (2) and Lock et al. (3), balloon mitral valvotomy (BMV) has evolved into an effective therapeutic modality for patients with MS, providing satisfactory short- and intermediate-term results. Many clinical trials (4–8) have established the safety and efficacy of this technique when offered as an elective procedure. Turi et al. (9) found comparable hemodynamic improvement after elective BMV and surgical commissurotomy. Thus, BMV has emerged as an attractive alternative to surgical treatment for selected patients. However, the results of elective BMV cannot be extrapolated to severely ill patients who undergo emergent relief of MS and is especially true for emergent operations because general anesthesia, thoracotomy and cardiopulmonary bypass have much higher risks in these patients, who often present with multiorgan failure. Although some earlier studies of BMV (10,11) included a few such critically ill patients, they remain poorly characterized as a group. The present study therefore sought to evaluate the feasibility, efficacy and safety of emergent BMV in patients with cardiac arrest, cardiogenic shock or refractory pulmonary edema to provide better definition of factors associated with both favorable and unfavorable outcomes in these patients.

Methods

This was a retrospective study carried out at a tertiary referral center in Mumbai, India.

Patients. Data from 558 patients with MS undergoing percutaneous BMV from January 1, 1993 to December 31, 1994 were reviewed. Of these 558 patients, 40 underwent BMV as an emergent procedure (group I) and 518 as an elective procedure (group II). The inclusion criteria for group I were severe MS (mitral valve [MV] area <1.0 cm²) and any of the
following: 1) Cardiogenic shock, defined as systolic blood pressure <80 mm Hg with evidence of tissue hypoperfusion in the form of weak peripheral pulses; cold extremities; oliguria (urinary output <0.5 ml/kg per hr); or altered sensorium, which persisted despite vigorous medical treatment, including inotropic support. 2) Refractory pulmonary edema, defined as persistent pulmonary edema and inability to maintain adequate oxygenation (Pao2 ≥60 mm Hg) without ventilatory support despite adequate diuretic therapy and optimal treatment to control precipitating causes, such as chest infection, anemia and rapid ventricular rates in atrial fibrillation. 3) Postcardiac arrest state, which included patients who underwent successful cardiopulmonary resuscitation (CPR) after in-hospital cardiac arrest.

All group I patients underwent a baseline clinical evaluation for severity of MS, estimation of pulmonary hypertension and factors related to the recent deterioration. They were initially managed in the intensive coronary care unit, and all attempts were made to stabilize their condition by means of optimal ventilatory and inotropic support. Efforts were also made to identify and treat the precipitating factors, such as anemia, infection, arrhythmias and drug (digoxin) toxicity. All patients underwent elective intubation, and positive pressure ventilation was initiated. Group I patients underwent BMV to provide relief of MS as a life-saving measure. The only exclusion criteria were (transthoracic) echocardiographic evidence of left atrial thrombus and mitral regurgitation (MR) grade >1. Severe subvalvular disease and calcification were not considered contraindications for the procedure.

Echocardiography. Two-dimensional echocardiography was performed along with spectral and color Doppler evaluation before and after the procedure. The MV apparatus of each patient was assessed according to the Wilkins et al. (12) scoring system. Higher scores represented more deformed valves. Doppler echocardiography along with color flow mapping was used for assessing MV area, MV gradients and pulmonary artery pressure (PAsP) and for quantifying MR severity before and after the procedure. MR was graded as 0 to 3 according to regurgitant jet area/leaflet area ratio: grade 0 = absence of MR; grade I = MR <20%; grade 2 = MR 20% to 40%; grade 3 = MR >40%. Echocardiographic variables analyzed for differences between the two groups included MV area by planimetry and pressure half-time, MV gradients, left atrial size, left ventricular end-systolic volume, left ventricular end-diastolic volume, MR grade and PAsP.

Cardiac catheterization. Patients whose general condition necessitated artificial ventilation received general anesthesia with vecuronium (0.08 to 0.1 mg/kg body weight) with nitrous oxide supplementation. Left femoral artery and venous sheaths were introduced. Pigtail and NIH catheters were used for left and right heart catheterization, respectively. Oxymetric and pressure data were obtained before the procedure. Cardiac output was calculated using the Fick principle. Transseptal puncture was performed through the right femoral vein by previously described techniques (13,14). Injection of contrast medium through the Brockenborough needle was used to identify the interatrial septum and to confirm entry into the left atrium. After transseptal puncture, 100 U/kg of heparin was administered. The transmitral gradient (TMG) was then measured, and BMV was performed using the Inoue balloon technique (2). A conservative approach to balloon sizing was used to minimize the chance of producing MR in group I patients. The first inflation was usually adjusted to 4 mm below the optimal diameter ([height/10] + 10 cm), with subsequent stepwise increments of 1 mm (15). The end point of dilation in group I was at least a 50% reduction in the mean transvalvular gradient or a final mean gradient of <8 mm Hg (whichever was lesser) or the occurrence of acute MR. In group II patients, every effort was made to minimize the pressure gradients without oversizing the balloon, which could cause MR. Immediately after BMV, all hemodynamic measurements were repeated without altering the ventilatory settings. These included determination of the transvalvular pressure gradient, estimation of systemic and PAsP and oxymetry. MR was assessed clinically and hemodynamically and by color Doppler.

Follow-up. Twenty of 26 survivors were followed up and assessed for New York Heart Association functional class, estimation of effort tolerance by a treadmill exercise test, occurrence of restenosis and MR. Serial echocardiograms were obtained for evaluation of MV area, TMGs, PAsP and MR severity.

Definition of success. Emergent BMV (group I) was deemed successful if there was an improvement in clinical status, with a significant reduction in TMG (as outlined earlier for the end point of dilation); less than grade 2 MR, with resolution of pulmonary edema; and improvement in tissue perfusion. Elective BMV (group II) was considered successful if the final MV area was >1.5 cm² or the gain in MV area was >50% than the predilation MV area, with MR less than grade 2. BMV in group I was performed as a life-saving measure by providing enough relief of the stenosis without running the risk of producing MR (by undersizing the balloon). In group II the goal was to provide an optimal hemodynamic result. Different criteria were thus used for judging success in the two groups, the criteria being less stringent in group I.

Statistical analysis. Continuous variables are reported as mean value ± SD. A p value <0.05 was considered significant. Comparisons of hemodynamic variables within a group and between the two groups (emergent [group I] and elective
Table 1. Hemodynamic Variables Before and After Balloon Mitral Valvotomy and at Follow-Up in Group I Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before BMV</th>
<th>After BMV</th>
<th>At Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV area (cm²)</td>
<td>0.74 ± 0.17</td>
<td>1.51 ± 0.38</td>
<td>1.4 ± 0.26</td>
</tr>
<tr>
<td>PAsP (mm Hg)</td>
<td>64 ± 14</td>
<td>50 ± 11</td>
<td>54 ± 13</td>
</tr>
<tr>
<td>LAP (mm Hg)</td>
<td>24 ± 8</td>
<td>13 ± 7</td>
<td></td>
</tr>
<tr>
<td>Peak TMG (mm Hg)</td>
<td>29 ± 6</td>
<td>16 ± 8</td>
<td></td>
</tr>
<tr>
<td>Mean TMG (mm Hg)</td>
<td>21 ± 8</td>
<td>6 ± 4</td>
<td></td>
</tr>
<tr>
<td>LVEDP (mm Hg)</td>
<td>3.5 ± 2.9</td>
<td>7.1 ± 3.8</td>
<td></td>
</tr>
<tr>
<td>CO (liters/min)</td>
<td>2.0 ± 0.6</td>
<td>3.2 ± 0.7</td>
<td></td>
</tr>
</tbody>
</table>

Data presented are mean value ± SD. BMV = balloon mitral valvotomy; CO = cardiac output; LAP = left atrial mean pressure; LVEDP = left ventricular end-diastolic pressure; MV = mitral valve; PAsP = pulmonary artery systolic pressure; TMG = transmitral gradient.

percutaneous transvenous mitral commissurotomy [group II]) were made using the student t test.

Baseline characteristics contributing to fatal outcome were identified by multivariate analysis. Univariate (chi-square and t test) analysis was used to determine the differences in the two groups, and multiple logistic regression was subsequently performed using the variables to determine which of them independently correlated with outcome.

Results

Baseline characteristics. Patients who underwent emergent BMV were older than those who underwent elective BMV (40 ± 13 vs. 31 ± 9 years, p < 0.05). Of the 40 group I patients, 26 (65%) were in cardiogenic shock, 11 (27.5%) had refractory pulmonary edema, and 3 (7.5%) had undergone successful CPR for cardiac arrest. Four patients in the cardiogenic shock group also had pulmonary edema, and all three patients in the cardiac arrest group were in cardiogenic shock after resuscitation. When the two groups were compared, atrial fibrillation was more frequent (30% vs. 9%, p < 0.05), MV score was higher (7.4 ± 1.2 vs. 6.4 ± 1, p < 0.001), MV area was lower (0.74 ± 0.17 vs. 0.86 ± 0.14, p < 0.001), and PAsP was higher (64 ± 14 vs. 51 ± 12 mm Hg, p < 0.001) in group I.

Post-BMV outcome. Twenty (60%) of 40 patients in group I had an uneventful recovery after the procedure. Of the remaining 16 patients, 14 (35%) died, including 4 who developed grade 3 MR. An additional two patients who developed grade 3 MR survived after emergent MV replacement. These adverse outcomes were more commonly seen in patients with high MV scores, and occurred in 5 of 24 patients with an MV score >8 and in 11 of 16 with an MV score ≥8 (p < 0.01). In group I, 7 of 14 deaths were related to BMV because of severe MR or failed BMV, or both and 7 were unrelated to BMV (4 from septicemic shock, 3 from multiple organ failure). Hemodynamic variables before and after BMV and at follow-up in group I survivors are presented in Table 1.

Age, gender, presence of pneumonia, pulmonary edema, congestive cardiac failure, atrial fibrillation, systemic systolic blood pressure <80 mm Hg, acute renal failure, PaO₂ <60 mm Hg, time from admission to BMV, hemoglobin level, MV score, PAsP and cardiac output were assessed by univariate analysis. Continuous variables were converted into two discriminant groups by appropriately selecting the cutoff points to assess their contribution to mortality. Of these variables, systemic systolic blood pressure <80 mm Hg (p = 0.04), PaO₂ <60 mm Hg (p = 0.04), MV score ≥8 (p = 0.031), cardiac output <3.15 liters/min (p = 0.0047) and PAsP >65 mm Hg (p = 0.025) were found to be significant. Baseline variables were also analyzed in a multivariate model to account for the interactions between various confounding variables. Using a stepwise logistic regression model, MV score ≥8 (p = 0.008), PAsP ≥65 mm Hg (p = 0.023) and cardiac output ≤3.15 liters/min (p = 0.001) were found to be significant predictors of fatal outcome.

Postmortem analysis. Postmortem examination of the heart was performed in all patients who died after emergent BMV. Table 2 displays the MV morphologic findings. Nine patients had commissural splitting of the MV; both medial and lateral commissures were split in five patients; and only one commissure was split in the remaining four patients. Seven of the nine patients with adequate commissural splitting died secondary to multiorgan failure or septicemic shock and were considered to have died of causes “unrelated to the procedure.” The other two patients with commissural splitting also developed significant MR. In five patients neither commissure had been split, including two with MR. All four patients had MR (leaflet tear in three, chordal rupture in one). The seven patients who died after failed BMV or MR or both were considered to have died of causes “related to the procedure.”

Follow-up of patients with emergent BMV. There were 26 survivors in group I, of whom 2 underwent MV replacement for acute MR. Thus, emergent BMV was successful in 24 of 40 patients. Follow-up data were available in 20 of 24 patients (mean follow-up 8.2 months, range 1 to 16). Clinical assessment revealed that 15 patients were in functional class I, 4 were in class II, and 1 was in class III. A treadmill test performed with the Bruce protocol in these 20 patients revealed a mean exercise duration of 8.4 ± 1.8 min. Table 1 shows that the MV area, PAsP and peak MV gradient at follow-up were similar to those observed immediately after BMV, indicating a sustained clinical and hemodynamic improvement after BMV. No patient had mitral restenosis.

Discussion

The present study evaluated the feasibility and safety of BMV in critically ill patients who present with cardiogenic shock and resistant pulmonary edema and in those successfully resuscitated after cardiopulmonary arrest. An attempt was made to identify baseline variables that could have contributed to an unfavorable outcome, even after a technically successful procedure.

Because of socioeconomic constraints, many patients in India do not undergo elective relief of MS and present to the hospital in an advanced stage, with pulmonary edema, low cardiac output or cardiogenic shock. Often these patients have
a precipitating event, such as respiratory infection, anemia and atrial fibrillation, that leads to sudden deterioration. Surgical commissurotomy for emergency relief has high mortality because of these associated factors. According to Barlow (16), the operative mortality rate for emergency closed surgical valvotomy is up to 25%. In our study, the mortality rate was 40%. However, this needs to be considered in the context of the poor general condition of our patients (i.e., multiple organ failure, significantly deformed valves and nonavailability of surgical interventions for logistic reasons). Despite a high mortality rate, emergent BMV is an acceptable alternative for these patients, almost all of whom will die without mechanical relief. Moreover, unlike surgical relief, BMV can be performed without thoracotomy and significant blood loss.

**Emergent BMV results.** Emergent BMV was successful in 24 patients. The procedure was regarded as unsuccessful in the 14 patients who died after BMV and in 2 who developed severe MR but survived after MVR. Of the 14 patients who died, BMV was technically “successful” in 7 in relieving the MS without producing acute MR. Despite adequate relief of MS, these patients succumbed either to septicemic shock or multi-organ failure. In the remaining seven patients, BMV was unsuccessful because of failure to split the commissures or development of significant MR. Two other previous studies (10,11) have reported the results of emergency BMV. Mu et al. (10) studied 10 patients; patient age, incidence of atrial fibrillation, MV scores, and MV gradients were comparable to those of our patients. The higher success rate of 70% in their series is probably due to the better general condition of their patients at presentation, which is also suggested by the fact that seven of our patients died despite adequate relief of the stenosis. Patel et al. (11) similarly reported good results in 12 young patients with intractable heart failure undergoing BMV. In their series, the patients were younger, with relatively better MV morphology and a shorter duration of the disease.

Ideally, group I patients should have undergone transesophageal echocardiography before BMV to identify left atrial or appendage thrombus because they were at higher risk for thromboembolism in view of the high incidence of atrial fibrillation, low cardiac output and advanced age. However, it is remarkable that none of our patients had any thromboembolic complications. Transesophageal echocardiography was not performed in our patients because this modality was not available to us during the study period, and it was not feasible to transfer the patients elsewhere.

**Problems of emergent BMV.** In the present study emergent BMV was undertaken in critically ill patients and required a well trained team to rapidly and efficiently perform the procedure. All 40 cases were attempted only after the total number of cases done at our center was >500, with a mortality rate of elective procedures <1%. Our patients had low cardiac output, were receiving inotropic support and had tachycardia; hence, hemodynamic assessment of MV gradients and pulmonary artery pressures was often difficult. In such patients the end point of the procedure was defined on the basis of cardiac index rather than TMG. In some patients with a high PAsP and associated tricuspid valve regurgitation and large right atria, the transseptal puncture was also technically demanding. The Inoue balloon technique was preferred over the double-balloon technique because the former is simpler, can be performed by a single operator and is quicker (17). Post-BMV management of the patients was difficult in view of cardiac cachexia, severe pulmonary hypertension, respiratory infections, impaired renal and cerebral function and stiff lungs, which persisted for some time, even after the mechanical relief.

### Table 2. Pathologic Findings After Emergent Balloon Mitral Valvotomy

<table>
<thead>
<tr>
<th>No.</th>
<th>Age (yr)/ Gender</th>
<th>Commissure Fractured</th>
<th>Leaflet Thickening</th>
<th>Subvalvular Disease</th>
<th>Calcification</th>
<th>Specific Observation</th>
<th>Probable Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54/F</td>
<td>Both</td>
<td>Sev</td>
<td>Sev</td>
<td>Mild</td>
<td>AML tear</td>
<td>MR</td>
</tr>
<tr>
<td>2</td>
<td>37/M</td>
<td>One</td>
<td>Sev</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>MOF</td>
</tr>
<tr>
<td>3</td>
<td>51/M</td>
<td>Neither</td>
<td>Sev</td>
<td>Sev</td>
<td>None</td>
<td>—</td>
<td>Failed BMV*</td>
</tr>
<tr>
<td>4</td>
<td>24/M</td>
<td>One</td>
<td>Sev</td>
<td>Sev</td>
<td>Mod</td>
<td>PML tear</td>
<td>MR</td>
</tr>
<tr>
<td>5</td>
<td>35/F</td>
<td>Both</td>
<td>Mod</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>Septicemic shock</td>
</tr>
<tr>
<td>6</td>
<td>42/M</td>
<td>Both</td>
<td>Mod</td>
<td>Mild</td>
<td>None</td>
<td>LA</td>
<td>MOF</td>
</tr>
<tr>
<td>7</td>
<td>38/F</td>
<td>Both</td>
<td>Mod</td>
<td>Mild</td>
<td>None</td>
<td>—</td>
<td>Septicemic shock</td>
</tr>
<tr>
<td>8</td>
<td>44/F</td>
<td>One</td>
<td>Mod</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>Septicemic shock</td>
</tr>
<tr>
<td>9</td>
<td>29/M</td>
<td>One</td>
<td>Sev</td>
<td>Mild</td>
<td>None</td>
<td>—</td>
<td>MOF</td>
</tr>
<tr>
<td>10</td>
<td>25/F</td>
<td>Neither</td>
<td>Sev</td>
<td>Sev</td>
<td>Mod</td>
<td>PML tear</td>
<td>MR, failed BMV</td>
</tr>
<tr>
<td>11</td>
<td>40/M</td>
<td>Both</td>
<td>Sev</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>Septicemic shock</td>
</tr>
<tr>
<td>12</td>
<td>51/F</td>
<td>Neither</td>
<td>Sev</td>
<td>Sev</td>
<td>Mild</td>
<td>Chordal rupture</td>
<td>MR, failed BMV</td>
</tr>
<tr>
<td>13</td>
<td>48/F</td>
<td>Neither</td>
<td>Mod</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>Failed BMV*</td>
</tr>
<tr>
<td>14</td>
<td>46/F</td>
<td>Neither</td>
<td>Mod</td>
<td>Mod</td>
<td>None</td>
<td>—</td>
<td>Failed BMV*</td>
</tr>
</tbody>
</table>

* Eventually resulted in unrelieved cardiogenic shock and death. AML = anterior mitral leaflet; BMV = balloon mitral valvotomy; F = female; LA = left atrial; M = male; Mod = moderate; MOF = multiple organ failure; MR = mitral regurgitation; PML = posterior mitral leaflet; Pt = patient; Sev = severe.
The problems were magnified in those with failed BMV and severe MR.

Follow-up. Most of the patients who were discharged from the hospital after the emergent BMV remained free from symptoms or were mildly symptomatic, which was gratifying in view of their poor state at presentation. The increase in MV area and the decrease in PAsP and TMG persisted at follow-up. Restenosis was not seen at intermediate follow-up.

Pathologic features of BMV: implications for mechanisms and complications. The basic pathoanatomic features of the MV rendered stenotic by virtue of RHD provide a rational basis for the success of both operative and balloon catheter intervention: The fundamental pathologic feature limiting leaflet mobility is fusion of one or both commissures (18). Thus, despite the fact that the leaflets are typically thickened and may at times contain calcific deposits, the orifice area can be significantly augmented by splitting the fused commissures. In the present study the success of BMV was related to satisfactory splitting of fused commissures. Failure to achieve success was related to inability to traverse or dilate a severely diseased MV because of severe commissural fusion and subvalvular disease. Among the group I 14 patients who died, only 1 was assessed as having grade 4 subvalvular affection at echocardiography. However, at autopsy, five of these patients had severe subvalvular affection in the form of complete fusion of the chordae and papillary muscles. Therefore, transthoracic echocardiographic estimation of subvalvular deformity in fact underestimated the degree of subvalvular disease. Whether such an understimation also occurred in group II is not known, as the mortality rate in group II was too low to draw any meaningful conclusions. The other major complication of the present study was MR. The mechanism of severe MR after BMV was multifactorial. MR was precipitated by either a tear of a commissure or a leaflet, rupture of the chordae or incomplete closure after splitting of the commissures because of rigid valve leaflets or shortened chordae, or both.

Limitations of the study. This was not a randomized study comparing BMV with surgical intervention. However, prospective randomization would be difficult because many candidates with highly deformed valves on echocardiography are not considered eligible for closed operation, at least at our hospital. Therefore, superiority of BMV over surgical intervention could not be established. Four of the 24 patients with successful emergent BMV were lost to follow-up.

Conclusions. The patients presenting for emergent BMV were in a critical clinical and hemodynamic state and were significantly older, with a higher incidence of atrial fibrillation, a smaller MV area and a higher PAsP and with MV apparatus that appeared more deformed on two-dimensional echocardiography. High MV score and PAsP and low cardiac output contribute significantly to in-hospital mortality. Despite high mortality and morbidity, emergent BMV is arguably the only viable option for these critically ill patients.

We are grateful to Dilip Karnad, MD for useful suggestions in manuscript preparation and help with the statistical analysis.

References