Percutaneous Balloon Mitral Valvuloplasty: A Review

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Several diseases have been acknowledged as pathological causes for mitral valve stenosis (MS), of which rheumatic heart disease is the most prevalent. Rheumatic heart disease is a chronic manifestation of rheumatic carditis, which occurs in 60% to 90% of cases of rheumatic fever. Rheumatic fever is a late sequela to Group A β-hemolytic streptococcal infection of the throat. The initial rheumatic fever results only in an edematous inflammatory process, leading to the fibrinoid necrosis of the connective tissue and cellular reactions. The initial valvulitis results in verruciform deposition of fibrin along the closing portion of the leaflets. Although all of the cardiac valves may be involved by this rheumatic process, the mitral valve is involved most prominently. The endocardial lesion most often leaves permanent sequela resulting in valvular regurgitation, stenosis, or both. Stenosis of this valve occurs from leaflet thickening, commissural fusion, and chordal shortening/fusion due to the above described pathological process.

Rheumatic Heart Valve Disease Is Still Epidemic in Asia

The decrease of the incidence of rheumatic heart disease in developed countries had already begun in 1910, and it is now below 1.0 per 100,000. On the other hand, the occurrence rate of rheumatic heart disease in developing countries remains substantial. Because the decline in the prevalence of rheumatic fever in industrialized nations started even before the era of penicillin and thus was related to improved living standards, the continued prevalence of rheumatic heart disease in undeveloped or developing countries is related not only to the limited availability of penicillin but to their socioeconomic status (ie, overpopulation, overcrowding, poverty, and poor access to medical care).

According to the annual report by the World Heart Federation, an estimated 12 million people are currently affected by rheumatic fever and rheumatic heart disease worldwide, and high incidence rates are reported in the Southern Pacific Islands. Several studies were conducted on the prevalence of rheumatic heart disease, reporting 0.14/1000 in Japan, 1.86/1000 in China, 0.5/1000 in Korea, 4.54/1000 in India, and 1.3/1000 in Bangladesh.

In rapidly evolving Asian countries, awareness of rheumatic heart disease has prevailed along with the widespread use of transthoracic echocardiography. Furthermore, demands for adequate medical therapies are expanding in tandem with explosive socioeconomic growth that may contribute to expanding use of percutaneous balloon mitral valvuloplasty (PBMV).

Percutaneous Balloon Mitral Valvuloplasty: The Concept

Before the advent of PBMV, most patients with symptomatic MS were treated with surgical mitral commissurotomy, either open or closed. Closed mitral commissurotomy was first described by Harken and Bailey in the late 1940s. Subsequently, after the development of cardiopulmonary bypass, the open surgical commissurotomy replaced the closed technique in most countries in the late 1960s and early 1970s. In 1982, Kanji Inoue, a Japanese cardiac surgeon, first developed the idea that a degenerated mitral valve could be inflated using a balloon made of strong yet pliant natural rubber. This concept was similar to the already abandoned closed surgical technique at that time. At first, this unique technique was largely limited to the Far East Asia, whereas in most of the other countries traditional cylindrically shaped balloons, which were initially developed for pulmonic valvuloplasty, were utilized for mitral valvuloplasty. Lock et al in India first reported the use of such a cylindrical balloon for mitral valvuloplasty. Subsequently, the idea of a double-balloon technique was introduced from Saudi Arabia as a potential alternative method for balloon commissurotomy. The double-balloon technique requires that 2 guidewires be positioned in the left ventricular apex, through which 2 floating balloon catheters are then advanced across the mitral valve orifice. Although the double-balloon technique is surely effective, it is more technically demanding and thus often requires a longer procedure time, which may lead to inadvertent complications. The guidewire positioned in the left ventricular apex sometimes induces perforation of the apex, leading to cardiac tamponade. In fact, PBMV using a single Inoue balloon yields equivalent efficacy when compared with the double-balloon technique and with lower procedural risks. Today, therefore, Inoue’s single-
balloon technique has become the most popular method for performing PBMV in most parts of the world.

The mechanism of PBMV is the same as the already abandoned closed mitral commissurotomy.11 Pathological studies have disclosed that the main mechanism of successful PBMV is a fracture of the commissures. In comparison to surgical mitral commissurotomy, PBMV has shown equal or better12,13 success rates and comparable restenosis rates.13 Randomized trials comparing PBMV to closed commissurotomy have shown that PBMV is superior to closed commissurotomy, providing a larger valve area and better long-term durability.14

Echocardiography Plays a Major Role in Patient Selection for PBMV

Indications for PBMV

The management of symptomatic and severe MS is described comprehensively in recent guidelines published jointly by the American Heart Association (AHA) and the American College of Cardiology (ACC)15 and in guidelines published by the European Society of Cardiology (ESC)16 (Figure 1). In the case of moderate or severe MS, one has to assess the anatomy of the mitral valve meticulously with regard to the feasibility and safety of PBMV. As shown in Table 1, the most widely used echocardiographic parameter is the Wilkins score, which takes into consideration the anatomy of the leaflet, the commissures, and the subvalvular apparatus.17 The scoring system assigns a point value from 1 to 4 for each of (1) valve calcification, (2) leaflet mobility, (3) leaflet thickening, and (4) subvalvular apparatus degeneration. A mitral valve with a score <8 to 9 with no more than moderate mitral regurgitation is deemed the best candidate for PBMV. In patients with a score >9 to 10, especially with more than moderate mitral regurgitation, surgical therapy should be advised except in cases with serious comorbidities.

A simpler echocardiographic classification for the stenotic mitral valve is the Lung and Cormier score18 (Table 2). This score is unique for taking the length of the chordae into consideration.

A limitation of both scoring systems is the lack of information on the location of valve abnormalities in relation to the commissures, which may influence the results of PBMV.19,20 As PBMV theoretically helps resolve MS by splitting the commissures, a valve with a bilateral commissural fusion could benefit more fully. Conversely, a valve without any commissural fusion, in which rigid leaflets or...

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Table 1. Wilkins Score

<table>
<thead>
<tr>
<th>Grade</th>
<th>Mobility</th>
<th>Thickening</th>
<th>Calcification</th>
<th>Subvalvular Thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Highly mobile with only leaflet tips restricted</td>
<td>Leaflets near normal in thickness (4-5 mm)</td>
<td>A single area of increased echo brightness</td>
<td>Minimal thickening just below the mitral leaflets</td>
</tr>
<tr>
<td>2</td>
<td>Leaflet mid portions and base portions have normal mobility</td>
<td>Midleaflets normal, considerable thickening of margins (5-8 mm)</td>
<td>Scattered areas of brightness confined to leaflet margins</td>
<td>Thickening of chordal structures extending to one of the chordal length</td>
</tr>
<tr>
<td>3</td>
<td>Valve continues to move forward in diastole, mainly from the base</td>
<td>Thickening extending through the entire leaflets (5-8 mm)</td>
<td>Brightness extending into the mid portions of the leaflets</td>
<td>Thickening extended to distal third of the chords</td>
</tr>
<tr>
<td>4</td>
<td>No or minimal forward movement of the leaflets in diastole</td>
<td>Considerable thickening of all leaflet tissue (&gt;8-10 mm)</td>
<td>Extensive brightness throughout much of the leaflet tissue</td>
<td>Extensive thickening and shortening of all chordal structures extending down to the papillary muscle</td>
</tr>
</tbody>
</table>

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annulus gives rise to orifice stenosis, may not benefit from commissurotomy because the leaflets or subvalvular apparatus could fracture. In addition, the presence of severe or bilateral calcification on the commissures could predict poor outcome due to worsening mitral regurgitation postprocedureally21 or a suboptimal increase in the valve area.22,23 Whichever scoring system is adopted, the success of PBMV requires that the pliability of the leaflet and the degree of degeneration and calcification of the commissures, subvalvular apparatus, annulus, and the leaflets be meticulously assessed.

To detect thrombus in the left atrium or left atrial appendage, transesophageal echocardiography should be performed before performing PBMV. At our institute, we never perform PBMV if we find thrombus in the left atrium or left atrial appendage. Although some investigators have insisted that PBMV can be safely performed even when thrombus is present in the left atrial appendage,24 this therapeutic approach should be seriously discouraged. If thrombus is found, PBMV should be postponed and the patient should be started on warfarin with the prothrombin time–international normalized ratio controlled at a relatively higher level for 3 to 6 months, after which transesophageal echocardiography should be repeated to confirm the disappearance of the clot. If the thrombus has disappeared, PBMV can then be safely performed, or if the thrombus remains, surgical intervention on the mitral valve along with removal of the thrombus should be recommended.

Controversies about indications for PBMV exist in cases with (1) asymptomatic moderate (mitral valve area 1.0 to 1.5 cm²) to severe (mitral valve area <1.0 cm²) MS, (2) symptomatic mild (mitral valve area >1.5 cm²), and (3) symptomatic severe MS with unfavorable anatomic characteristics.

In asymptomatic moderate to severe MS, both guidelines advocated that early use of PBMV be considered for patients with high risk of embolism (ESC: paroxysmal atrial fibrillation [Class IIa], history of embolism [Class IIa], evidence of atrial spontaneous contrast echo [Class IIa]; AHA/ACC: new onset of paroxysmal atrial fibrillation [Class IIb] or hemodynamic decompensation; ESC: high pulmonary artery systolic pressure [Class IIa], need for major surgery [Class IIa], and pregnancy [Class IIa]; and AHA/ACC: pulmonary hypertension at rest [Class I] or during exercise [class I] and poor exercise tolerance [Class I] when patients have favorable clinical/anatomic characteristics). If patients complain of dyspnea on exertion that is out of proportion to the degree of MS, the ACC/AHA guideline recommends use of exercise Doppler echocardiography25 to reveal occult hemodynamically significant MS.

The prognostic significance of such hemodynamic compromise at exercise, however, remains unclear, and therefore application of PBMV for asymptomatic mild MS should be carefully reviewed in each case. The ACC/AHA guidelines recommend use of PBMV in these scenarios (Class IIb). On the other hand, mitral valve area >1.5 cm² is considered one of the contraindications to PBMV according to the ESC guidelines.

Although the underlying mitral valve morphology is the factor of greatest importance in determining outcome after the therapy, PBMV can be offered as the initial treatment (ESC: Class IIa, AHA/ACC: Class IIa) for patients with unfavorable anatomic characteristics but no unfavorable clinical characteristics (ESC: Class IIa; the ESC defines unfavorable clinical characteristics as absence of several factors: old age, New York Heart Association [NYHA] class IV, severe pulmonary hypertension, atrial fibrillation and history of commissurotomy) or have high surgical risk (AHA: Class IIa).

Contraindications to PBMV are summarized in Table 3. In addition to these, a MS with no commissural fusion should be considered as a relative contraindication, as previously described. PBMV should be considered first-line therapy in most cases of severe MS without obvious contraindications.2

### Selection of Appropriate Balloon Size

Selection of the appropriate balloon size is one of the most critical factors for accomplishing this procedure (ie, for releasing the stenotic mitral orifice without causing extensive damage to the commissures, leaflets, and subvalvular apparatus leading to excessive mitral regurgitation). For selecting the appropriate balloon size, some researchers have advocated methods to select balloon size with the patient’s height26 or body surface area27 as a reference. A simple equation to obtain the reference size (height [cm]/10 + 10) has been proposed.28 The obvious point should be made, however, that the relationship of one’s height to the diameter of the mitral valve orifice is not necessarily linear. Furthermore, the operator must remember that annular calcification will affect the size of the mitral valve orifice regardless of the patient’s physical constitution. To avoid undesired extensive injury to the mitral valve apparatus, we select the balloon size by directly measuring the mitral annular diameter using 2-dimensional echocardiography. The mitral annular diameter can be measured on the apical 4- or 2-chamber view during mid- to end-systole. Measuring mitral annular diam-
seriously complications (ie, perforation and tamponade). enbrough procedure but also as a monitor to early detect diography can be used not only as guidance for the Brock-


catheterization is performed via a standard Brockenbrough puncture site for the Brockenbrough needle. Transseptal Right atriography is then performed to determine the septal portion that has the least pressure compliance, with which fixation of the balloon catheter is facilitated and the degenerated fused commissure(s) can be dilated substantially.

The procedure is always performed via a femoral approach with a 9F sheath in the vein and a 5F sheath in the artery, with the patient under light sedation. After bolus administration of 1000 U heparin, right heart catheterization is performed. Right atrio-phyography is then performed to determine the septal puncture site for the Brockenbrough needle. Transseptal catheterization is performed via a standard Brockenbrough procedure using anteroposterior views. While slowly withdrawing the Brockenbrough catheter from superior vena cava into the interatrial septum, the operator advances the Brockenbrough needle beyond the interatrial septum when the tip of the catheter falls into the fossa ovalis. Computed tomography or transesophageal echocardiography can be useful in identi-
yzing the anatomic location of the interatrial septum relative to the right atrium. Transesophageal or intracardiac echocardiography can be used not only as guidance for the Brockenbrough procedure but also as a monitor to early detect serious complications (ie, perforation and tamponade).

The PBMV Procedure

The Inoue Balloon catheter (Toray, Tokyo, Japan) is a 12F polyvinylchloride tube with a coaxial lumina. The balloon section is stiffened and slenderized when stretched by the insertion of a metal tube. The balloon size is pressure dependent and consists of 3 portions with slightly different compliance. As pressure is gradually added, the distal portion of the balloon inflates first, followed by the proximal portion. The unique part of the Inoue balloon is its middle waist portion that has the least pressure compliance, with which fixation of the balloon catheter is facilitated and the degenerated fused commissure(s) can be dilated substantially.

After advancing the Brockenbrough needle, a coiled-tip guidewire is placed into the left atrium through the Brockenbrough sheath. Then, we administer 9000 U of heparin to reduce the risk of a thromboembolic event during the manipu-

lation of catheters and wires in the left atrium. Anticoagu-
lution time is monitored during the procedures to maintain appropriate levels of anticoagulation.

In the next step, the Inoue balloon catheter is advanced over the coiled-tip wire. A system for accomplishing PBMV consists of the following devices: Inoue balloon catheter, metallic stiffening cannula (18 gauge, 80 cm in length) for stretching and stiffening the Inoue balloon catheter, guide- wire for PBMV (0.028 inches in diameter, 180 cm in length), dilator (14F polyethylene tube with a thinner tip 70 cm in length) for dilating the puncture site of the femoral vein and atrial septum, and a stylet (wire with J-shaped tip, 0.038 inches in diameter, 80 cm in length) for directing the Inoue balloon toward the mitral orifice. Once the balloon catheter has crossed the interatrial septum, the catheter should be placed in the left atrium so that the catheter forms a loop with the tip facing toward the mitral valve orifice. The tip of the balloon is inflated with 1 to 2 mL of contrast media, allowing blood flow to direct the balloon tip into the left ventricle. If advancement of the Inoue balloon proves difficult, the stylet is inserted in the balloon catheter, and the balloon catheter with stylet are moved together toward the mitral valve orifice. With the right anterior oblique view, which helps identify the proper line between the base and the apex, the deflated Inoue balloon catheter is advanced until the tip of the catheter has crossed the mitral valve into the left ventricle.

Once the balloon catheter has been inserted into the left ventricle, the distal portion of the balloon is inflated with contrast media using a specially graduated syringe. The catheter is then pulled until resistance is felt. During inflation of the balloon, the appearance of a deformed distal balloon may suggest entrapment in the subvalvular apparatus. In this situation, further inflation should not be performed and the balloon should be repositioned to a location that is more proximal to the mitral orifice to avoid trauma to the subval-

vular apparatus.

The Inoue balloon has a much less compliant portion in its waist that assists in the secure dilatation of the mitral valve orifice. Figure 3 shows the typical step-by-step appearance of the Inoue balloon catheter. Before placing the Inoue balloon catheter, we routinely select the balloon size by which valve orifice is finally dilated, as previously described.

After each dilatation, the operator should obtain the left atrial pressure through the middle port of the Inoue catheter and the left ventricular pressure through the pig-tail catheter simultane-
ously. If the pressure gradient between the left atrial pressure and the simultaneously obtained left ventricular pressure does not decrease, the balloon size is increased in 1-mm increments until the pressure gradient decreases or substantial worsening of mitral regurgitation occurs. In addi-
tion, 2-dimensional echocardiographic observations are per-
formed after each dilatation. To assess mitral valve orifice area after each dilatation, planimetry of the valve orifice with 2-dimensional echocardiography should be adopted rather than the pressure half-time method on continuous Doppler
waveform, because pressure half-time–derived orifice area might be inaccurate in this acute setting.30

If 1 of the 3 following events is encountered—decrease in the pressure gradient between the left atrium and the left ventricle, occurrence of significant mitral regurgitation, or substantial splitting of the commissure—further dilatation is not performed unless critical complications might otherwise ensue.31

**Immediate Results of PBMV**
The binary end point of immediate procedural success is most often a final valve area \( >1.50 \text{ cm}^2 \) without moderate or severe mitral regurgitation. After PBMV, mitral valve area approximately doubles in most successful cases. Mitral valve anatomy as assessed by 2-dimensional echocardiography is a strong predictor of the immediate results of PBMV. The previously described Wilkins score has a discriminant cut-off point at 8 according to analyses of the immediate results of PBMV. Whatever echo scoring system is used, older age, smaller valve area, previous commissurotomy, or baseline mitral regurgitation should be considered as potential predictors for poor immediate outcome with a similar predictive strength as valve calcification.18 In clinical practice, young patients (<50 years old) with favorable valve anatomy have usually showed particularly good immediate results.32–34

**Post-PBMV Complications**
Most of the adverse complications relevant to this procedure occur during the procedure12 (ie, during the process of interatrial septum puncture, manipulation of the Inoue balloon catheter in the left atrium, and commissurotomy of the mitral valve by Inoue balloon catheter). Major complications with regard to the Brockenbrough puncture are related to penetration of the Brockenbrough needle into the adjacent structure (ie, ascending aorta and the postatrial pericardial space). The most common serious complication is hemopericardium, with an incidence of 0% to 2.0%.35 When hemopericardium or rupture into the space surrounding the aortic root occurs, protamine sulfate should be administered to promote spontaneous hemostasis unless urgent surgical intervention is necessary.

Although relatively rare, unintended perforation by the tip of the Inoue catheter or guidewires while being manipulated in the cardiac chambers might happen in the left atrial appendage, the pulmonary veins, or the left ventricular apex because of the vulnerability of these structures. Detachment of undetected microthrombi in the left atrium or left atrial appendage by the catheter or guidewire tip also could occur. To avoid these mechanical complications, gentle manipulation of the guidewires and catheters should be required, and the Inoue catheter should be formed using the stylet, with the tip of the catheter properly directed toward the mitral valve orifice.

An increase of mitral regurgitation is another possible complication after commissurotomy; however, in most cases, the degree of mitral regurgitation slightly increases after PBMV without requiring surgical intervention. The mechanism of the increase or new appearance of mitral regurgita-
tion is reported to be excessive tearing of the commissures(s) or the posterior/anterior leaflet at noncommissural part, incomplete closure of a calcified leaflet, localized rupture of the subvalvular apparatus, and shortened chordate tendineae after splitting of the commissure(s). Severe mitral regurgitation is relatively rare, with a frequency ranging from 1.4% to 9.4%.33,36

Puncture by the Brockenbrough needle and by advancing the 9F catheter at the interatrial septum creates an iatrogenic left-to-right shunt at the interatrial level persisting for more than several months and, in some cases, years. These shunts, with a frequency of 10% to 90% dependent on the methods used for their detection, are usually small and restrictive and almost never become hemodynamically significant (Qp/Qs > 1.5).

Long-Term Results
Most patients with initial procedural success report significant functional improvement. When immediate results are suboptimal, the patient’s functional status does not improve or improves only transiently. Because the mechanism and background of MS may affect the long-term results of PBMV, analysis should be conducted in 2 different categories of the population: (1) in young patients with favorable valve anatomy who are the homogenous population mainly encountered in developing countries; and (2) in older patients with less-favorable valve anatomy, who are a much more heterogeneous group and who are seen in Western countries.

The best results of PBMV are observed in young patients who have MS with favorable anatomic characteristics (ie, pliable noncalcified valves and moderate impairment of the subvalvular apparatus). Published series from India and Tunisia have clearly demonstrated the safety and efficacy of PBMV in such patients.37,38 After PBMV, at least 90% of patients are alive without intervention on the mitral valve and with few or no symptoms 5 to 7 years after the procedure.

Randomized trials conducted in these young populations show that 3- and 7-year results of PBMV are as good as those obtained with open-heart commissurotomy49 and better than those with closed-heart commissurotomy.37

Fawzy et al40,41 reported an event-free survival rate of 79% at 10 years and 43% at 15 years in relatively younger patients (mean age 31 ± 11 years) and were significantly higher for patients with optimal valve anatomy (88% at 10 years, 66% at 15 years). They found that favorable valve anatomy, age, and postsurgical mitral valve area were predictors of event-free survival.

Iung et al43 reported an event-free survival (survival with freedom from repeat PBMV, mitral valve replacement, cardiac death, high NYHA class) rate of 61% at 10 years in >1000 patients (mean age 49 ± 14 years) with successful PBMV. Although favorable long-term prognosis largely depends on immediate procedural success, the prediction of late prognosis includes multiple factors including old age, unfavorable valve anatomy, high NYHA class, atrial fibrillation, low valve area after PBMV, high gradient after PBMV, and > grade 2 mitral regurgitation after PBMV.43,44

Suboptimal immediate results lead to relatively early intervention, which explains the presence of an early drop of event-free survival after the procedure. Conversely, some patients experience late functional deterioration many years after the procedure, which is likely related to mitral restenosis.45 Post-PBMV mitral restenosis is defined as a valve area < 1.5 cm² or a > 50% loss of the initial gain in valve area.46 Reportedly, the freedom from restenosis rates were 85% at 5 years, 70% at 10 years, and 44% at 15 years and were significantly higher (ie, 92% at 5 years, 85% at 10 years, and 65% at 15 years) for patients with optimal morphology.40,41 Repeat PBMV should be proposed as first-line therapy if patients had symptoms related to MS and showed only mild mitral regurgitation based on the observational evidence that the mechanism of mitral restenosis is primarily commissural refusion.47 In patients with incomplete commissural fusion, repeat PBMV might end in suboptimal results.48 In cases without any commissural fusion, mitral restenosis could be due to a rigid valve or subvalvular apparatus, and therefore repeat PBMV should be considered as contraindicated.

The presence and degree of post-PBMV mitral regurgitation play a part in long-term prognosis. When severe mitral regurgitation occurs after PBMV, the patient’s prognosis is relatively poor and surgical treatment is required at some point. The mechanism of post-PBMV mitral regurgitation is reported to be closely related to long-term prognosis.49 Although most mild but significant cases of mitral regurgitation are caused by commissural split, the causes of new appearance of severe mitral regurgitation are chordal rupture or leaflet laceration. Kim et al reported that patients with commissural mitral regurgitation had a significantly lower rate of mitral valve replacement than patients with noncommissural mitral regurgitation.49

PBMV for Special Patient Populations
A number of special patient subgroups are important to consider.

Post Surgical or Balloon Commissurotomy
PBMV can safely be performed for most patients after commissurotomy, either surgical or percutaneous. Two major mechanisms are responsible for valvular restenosis: commissural refusion and progression of subvalvular thickening/degeneration. Turgeman et al reported that patients with mitral restenosis caused by symmetrical commissural refusion obtain better results from repeat procedures compared with patients with restenosis in whom the pathological mechanism of restenosis is mainly subvalvular and commissures are not bilaterally fused but rather unilaterally or bilaterally split.48

With regard to the long-term prognosis of patients treated with repeat PBMV or with surgical replacement in cases of mitral restenosis after PBMV, several reports have supported safety and favorable outcome for repeat PBMV.50,51 However, the most recent study demonstrated a more favorable outcome for mitral valve replacement, especially in patients followed up for > 9 years.52

One report47 compared repeat PBMV for postintervention restenosis with initial PBMV for de novo MS relative to immediate results and long-term results. No significant differences were found between repeat and initial PBMV rela-
tive to good immediate results (postprocedural MVA >1.5 cm², mitral regurgitation <2/4) and freedom from restenosis rates at 10 years’ follow-up (93% versus 96%, and 58% versus 68%, respectively). Ten-year event-free survival rates were slightly higher for patients who underwent initial PBMV for de novo MS (54% versus 80%).

Pregnant Patients
Pregnancy can become a hemodynamic burden even in normal subjects by increasing the intravascular volume by 30% to 50% over nonpregnant levels. This hemodynamic change might result in an increase in the transmitial gradient and left atrial pressure, which may lead to acute pulmonary flash edema. Maternal mortality for patients with MS who are in NYHA class 1 and 2 is 0.4% and significantly higher (6.8%) for those in NYHA class 3 and 4, particularly during labor and delivery.53 Surgical commissurotomy is indeed effective for most of these patients but is reported to have maternal mortality between 1.7% and 3.1% and fetal mortality ranging from 5% to 33%.53,54 PBMV should be performed by experienced operators with abdominal and pelvic shielding and with minimum radiation exposure and should be avoided during the first trimester. With these precautions, PBMV can be safely performed. Esteves et al55 reported optimal immediate and long-term results in pregnant patients who underwent PBMV during the second trimester of their pregnancy.

Children and Adolescents
Characteristically, MS evolves through several fairly well-defined clinical stages. Specifically, a latent period has been identified of ~10 to 20 years before symptoms appear. In tropical and subtropical regions, however, progression may be more rapid.56 Tight MS was not a common lesion in children in Western countries even when rheumatic fever was rampant.57 Furthermore, it has been stated that only 50% of patients with premature MS show Aschoff bodies at surgery or autopsy.57 Questions on whether juvenile MS is a true variant of rheumatic MS remain to be answered. Several researchers have reported similar58 or even better59,60 success rates for PBMV in children with MS. Severe congenital MS is a rare mitral valve deformity with several anatomic subtypes: typical, supramitral ring mitral, parachute mitral valve, and double-orifice mitral valve. Although most patients with congenital MS can safely be treated by PBMV, higher rates of postprocedural exacerbation of mitral regurgitation due to tearing of the leaflet or subvalvular apparatus have been reported.61,62

Atrial Fibrillation/Thrombotic Formation
Atrial fibrillation occurs commonly in MS, affecting almost 40% of all patients. Atrial fibrillation in rheumatic MS is different in pathophysiology from atrial fibrillation in non-rheumatic disease. ACC/AHA guidelines suggest that PBMV can be a therapeutic option for patients with asymptomatic MS and with newer occurrence of atrial arrhythmias.15 Admittedly, after successfully relief of an obstructed mitral valve orifice, left atrial function improves, as evidenced by the reduced size of left atrial volume,63 improved left appendage flow velocity,64 and decreased intensity of spontaneous contrast echo.65 However, no large trials have shown an antiarrhythmic effect of PBMV.66 One promising study has shown that successful PBMV was strongly associated with a decreased thromboembolic risk in patients with MS and atrial fibrillation.67 Further studies are required to show beneficial effects of PBMV besides hemodynamic improvement.

Conclusion
Although the incidence of rheumatic fever and the prevalence of rheumatic heart disease as a sequela are decreasing in most Asian countries, a small but substantial occurrence of rheumatic MS exists and will continue to exist in Asia. The need for adequate understanding of indications, PBMV procedures, and assessment of results cannot be overemphasized.

Disclosures
None.

References
26. Vahanian A, Cormier B, Iung B. Percutaneous transvenous mitral com-
29. Cannan CR, Nishimura RA, Reeder GS, Ilstrup DR, Larson DR, Holmes 
30. Sutaria N, Northridge DB. Transoesophageal 
31. Vahanian A. How to do a mitral valvuloplasty. 
32. Nobuyoshi M, Hamasaki N, Kimura T, Nosaka H, Yokoi H, Yasumoto H, 
33. de Souza JA, Martinez EE, Jr., Ambrose JA, Alves CM, Born D, Buffolo 
34. Martinez-rios MA, Tovar S, Luna J, Eid-Lidt G. Percutaneous mitral commis-
35. Martinez-rios MA, Tovar S, Luna J, Eid-Lidt G. Percutaneous mitral commis-
36. Palacios IF, Sanchez PL, Harrell LC, Weyman AE, Block PC. Which patients benefit from percutaneous mitral balloon valvuloplasty? Preval-
38. Arora R, Kalra GS, Singh S, Mukhopadhyay S, Kumar A, Mohan JC, 
40. Reyes VP, Raju BS, Wynne J, Stephenson LW, Raju R, Fromon BS, 
43. Wilkins GT, Weyman AE, Abascal VM, Block PC, Palacios IF. Percu-
taneous balloon dilatation of the mitral valve: an analysis of echocardio-
44. Hickey MS, Blackstone EH, Kirklin JW, Dean LS. Outcome probabilities 
45. Wang A, Krasuski RA, Warner JJ, Pieper K, Kisslo KB, Bashore TM, 
46. Feinberg MS. Impact of atrioventricular compliance on pulmonary artery 
47. Fawzy ME, Fadel B, Al-Sergani H, Al Amri M, Hassan W, Abdulkheli, 
48. Fawzy ME, Fadel B, Al-Sergani H, Al Amri M, Hassan W, Abdulkheli K, 
49. Kim MJ, Song JK, Song JM, Kang DH, Kim YH, Lee CW, Hong MK, 
50. Iung B, Cormier B, Ducimetiere P, Porto JM, Nallet O, Michel PL, Acrar J, Vahanian A. Immediate results of percutaneous mitral commis-
51. Pathan AZ, Mahdi NA, Leon MN, Lopez-Cuellar J, Simosa H, Block PC, 
53. de Souza JA, Martinez EE, Jr., Ambrose JA, Alves CM, Born D, Buffolo 
54. Carvalho AC. Percutaneous balloon mitral valvuloplasty in com-
55. Nobuyoshi M, Hamasaki N, Kimura T, Nosaka H, Yokoi H, Yasumoto H, 
56. Fawzy ME, Shoukri M, Hassan W, Namibiar V, Stefadouros M, Canver 
57. Sutaria N, Shaw TR, Prendergast B, Northridge D. Transoesophageal 
58. Cannan CR, Nishimura RA, Reeder GS, Istrup DR, Larson DR, Holmes 
59. Chen WJ, Chen MF, Liu AS, Wu CC, Lee YT. Safety of percutaneous transvenous balloon mitral commissurotomy in patients with mitral ste-
60. Schwammenthal E, Vered Z, Agranot O, Kapilinsky E, Rabinowitz B, 
63. Wilkins GT, Weyman AE, Abascal VM, Block PC, Palacios IF. Percu-
taneous balloon dilatation of the mitral valve: an analysis of echocardio-
64. Hickey MS, Blackstone EH, Kirklin JW, Dean LS. Outcome probabilities 
65. Wang A, Krasuski RA, Warner JJ, Pieper K, Kisslo KB, Bashore TM, 
66. Fawzy ME, Fadel B, Al-Sergani H, Al Amri M, Hassan W, Abdulkheli K, 
67. Kim MJ, Song JK, Song JM, Kang DH, Kim YH, Lee CW, Hong MK, 
68. Iung B, Barbazza E, Michaud P, Helou S, Farah B, Berdah P, Michel PL, 
69. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
70. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
71. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
73. Palacios IF. Echocardiography can predict which patients will develop 
74. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
75. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
76. Palacios IF. Echocardiography can predict which patients will develop 
77. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
78. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
79. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
82. Fatkin D, Roy P, Morgan JJ, Feneley MP. Percutaneous balloon mitral valvulotomy with the Inoue single-balloon catheter: commissural mor-
84. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
86. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
89. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
90. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA, 
100. Padial LR, Freitas N, Sagie A, Newell JB, Weyman AE, Levine RA,


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