Valvular Heart Disease and Pregnancy

Part I: Native Valves

Uri Elkayam, MD, FACC, Fahed Bitar, MD
Los Angeles, California

Pregnancy in patients with valvular heart disease (VHD) continues to pose a challenge to both physicians and their patients and could be associated with an unfavorable maternal as well as fetal outcome. The purpose of this paper is to review the available clinical data and provide recommendations for the management of patients with VHD during gestation. (J Am Coll Cardiol 2005;46:223–30) © 2005 by the American College of Cardiology Foundation

The presence of valvular heart disease (VHD) due to both congenital and acquired etiologies in a pregnant patient continues to pose a challenge to clinicians and their patients (1,2). This condition increases the risk of pregnancy to both the mother and the fetus and requires specific care to avoid or at least minimize maternal morbidity and mortality and assure fetal well-being. The goal of this paper is to review the available information and provide recommendations for the management of patients with VHD during pregnancy.

GENERAL CONSIDERATIONS

Preconception evaluation. The management of women with VHD should ideally begin before conception. A careful cardiac examination and assessment of functional capacity are needed to determine the likelihood of the patients to tolerate the increased hemodynamic burden of pregnancy and the risk of complications during gestation. Preconception evaluation, therefore, should include a careful history and physical examination, a 12-lead electrocardiogram, an echocardiogram, and a Doppler study. In patients with a history of impaired or questionable functional capacity, an exercise test, preferably with measurement of oxygen consumption (3), is useful for an objective assessment of functional classification. The anticipated risk of pregnancy on the basis of the evaluation should be discussed with the patient and her family by both the cardiologist and the obstetrician. In anticipation of pregnancy, drugs with potential harm to the fetus (4), should be discontinued.

Antepartal and peripartal care. Antepartal care should include a joint obstetric and cardiologic evaluation with a frequency on the basis of the type and severity of the disease as well as the patient condition. In general, antenatal visits should be scheduled every month in women with mild disease and every 2 weeks in women with moderate and severe disease until 28 to 30 weeks and weekly thereafter until delivery. When drug therapy seems necessary, the smallest therapeutic dose of drugs known to be safe for the fetus should be used (4). In assessing a patient with VHD during pregnancy, it should be noted that the evaluation may be complicated by normal anatomical and functional changes of the cardiovascular system that may result in signs and symptoms that can mimic heart disease (5). These include fatigue, decreased exercise capacity, shortness of breath, palpitations, light-headedness, and even syncope. Physical examination often reveals increased jugular venous pulsation, leg edema, palpable right ventricular heave, and a systolic murmur (5). Therefore, in many cases it is imperative to use additional diagnostic tools to obtain accurate information about cardiac status before therapeutic decisions are made.

Labor and delivery. Timing and mode of delivery should be discussed and decided upon jointly by the obstetrician, cardiologist, and obstetric anesthesiologist. In general, vaginal delivery with appropriate anesthesia and shortening of the second stage is safe and can be performed in the majority of patients with VHD (6,7). Cesarean section is potentially associated with a higher rate of complications (8) and should usually be performed for obstetric indications and in the occasional patient with cardiac instability. Hemodynamic monitoring during labor and delivery is recommended in symptomatic patients and in patients with moderate or severe valvular stenosis, left ventricular dysfunction, and pulmonary hypertension.

Early puerperium. In spite of the blood loss associated with delivery, the early puerperium is associated with increased venous return to the heart caused by blood shift from the emptied uterus into the systemic circulation, decreased caval compression, and mobilization of fluid from the limbs and lower body (9). These hemodynamic changes can lead to heart failure (6,7) and require continued hemodynamic monitoring for 12 to 24 h after the delivery.

Antibiotic prophylaxis. Antibiotic prophylaxis has been recommended for patients with VHD who undergo manipulations or surgical procedures likely to result in bacteremia (10). The use of antibiotic prophylaxis, however, was not recommended by the last American Heart Association/American College of Cardiology practice guidelines for
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treatment for labor is given routinely in patients with VHD
devastating effect of endocarditis, prophylactic antibiotic
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occurred in women during delivery, and Furman et al. (15)
reported bacteremia in the postpartum in 9.4% of 968
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the relative low risk and cost of therapy, and the potential
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treatment for labor is given routinely in patients with VHD
in many institutions, including ours (17,18). The recom-
manded regimens for antibiotic prophylaxis include ampi-
cillin (2.0 g intramuscular [IM] or intravenous [IV]) plus
gentamicin (1.5 mg/kg, not to exceed 120 mg) given at
initiation of labor or within 30 min of a cesarean section,
followed by ampicillin (1 g IM or IV) or amoxicillin (1 g
orally) 6 h later. For patients allergic to ampicillin and
amoxicillin, vancomycin (1.0 g IV over 1 to 2 h) is
recommended instead (10).

### SPECIFIC VALVULAR LESIONS

**Mitril stenos** (MS). Mitril stenos is the most com-
monly encountered valvular lesion in pregnancy (6,7,17,18)
and is caused in almost all cases by rheumatic heart disease.
Although rheumatic MS is often accompanied by some
degree of mitral regurgitation (MR) (6,18), pregnancy-
related hemodynamic and symptomatic problems are
predominantly due to valve stenos. The pressure gradient
across the narrowed mitral valve may greatly increase during
pregnancy secondary to the physiological rise in heart rate
and stroke volume, which leads to an increase in left atrial
pressure and thus to the development or worsening of
symptoms, including dyspnea, decreased exercise capacity,
orthopnea, paroxysmal nocturnal dyspnea, and pulmonary
edema. Increased left atrial pressure can also result in atrial
arrhythmias (6,7), which may lead to a further acceleration
of ventricular rate and thus to additional hemodynamic
worsening and symptomatic deterioration.

**MATERNAL RISK.** Several reports published in recent years
on pregnancies in women with heart disease have provided
outcome information on over 400 patients with MS in
different parts of the globe (6,7,17–21). Hameed et al. (6)
published a case–control study of 46 pregnancies in 44
patients with MS who were compared with a healthy
control group of women matched for age, ethnicity, obstet-
ric and medical history, time of initial prenatal care, and year
of delivery. Twenty-eight of these cases were in the New
York Heart Association (NYHA) functional class I and 18
were in class II on their initial clinic visit, and of all 44
patients, 74% demonstrated clinical deterioration during
pregnancy. Maternal outcome was favorable in patients with
mild MS and comparable to their control; in contrast, there
was a significantly higher incidence of maternal morbidity in
women with moderate and severe MS, including the develop-
ment of heart failure, arrhythmias (atrial fibrillation or
supraventricular tachycardia), the need to start and/or in-
crease a dose of cardiac medications, and the need for
hospitalizations.

A later report by Silversides et al. (7) from Canada
described the outcome of 80 pregnancies in 74 women with
rheumatic MS, which was moderate in 36% and severe in
11% of the cases. Of these pregnancies, 35% were associated
with maternal cardiac complications, including pulmonary
edema in 31% and arrhythmias in 11%. The first episode of
pulmonary edema occurred in 60% of the patients in the
antepartum period at a mean gestational age of 30 ± 0.4
weeks, and 20% occurred in the setting of atrial tachyar-
hythmias. Of the nine women who developed arrhythmias
during pregnancy, 70% had atrial fibrillation and the rest
had supraventricular tachycardia. The incidence of maternal
complications was related to the severity of MS and was
67% in women with severe, 38% in those with moderate,
and 26% in those with mild MS. Barbosa et al. (19) reported
prognostic factors in 41 patients followed in Brazil between
1991 and 1999. The risk of maternal events, which included
progression of heart failure, need for cardiac surgery or
balloon mitral valvuloplasty, death, and thromboembolism,
was strongly associated with the severity of MS and NYHA
functional class before pregnancy. A strong association
between patients’ NYHA functional class and both maternal
and fetal complications was confirmed by Bhatla et al. (18),
who reported a retrospective analysis in 207 pregnancies in
women with cardiac disease who delivered ≥28 weeks; 71 of
these patients had MS.

Despite the high incidence of reported maternal morbid-
ity, maternal mortality associated with pregnancy in patients
with MS seems to be uncommon. No mortality was re-
ported in 124 pregnancies in women with MS reported by two tertiary-care facilities with high-risk obstetric/cardiology clinics in North America and in 71 cases treated in a high-volume center in India (6,7,18). Isolated cases of maternal death have been described in women with critical MS who were in NYHA functional class III and IV in other reports (16,20).

Although retrospective evaluations reported a low incidence of thromboembolism in patients with MS during pregnancy (17,18), Hameed et al. (22) have recently reported three patients who presented with clinically significant left atrial thrombus in the absence of atrial fibrillation that resulted in a stroke in one patient and partial occlusion of the mitral valve orifice leading to worsening of heart failure in another patient. The third patient had multiple, large left atrial thrombi that were successfully treated with low-molecular-weight heparin throughout the pregnancy. Because of these findings and the hypercoagulable state of pregnancy, these investigators have recommended strong considerations for anticoagulation prophylaxis during gestation in women with severe MS and enlarged left atrium, even in the absence of atrial fibrillation.

FETAL OUTCOME. A comparison of fetal outcome between women with MS and a well-matched control group of healthy women (6) demonstrated an important effect of MS on the incidence of preterm delivery (28% [moderate MS] vs. 6% [control] and 44% [severe MS] vs. 11% [control]) and intrauterine growth retardation (27% [moderate MS] vs. 0% [control] and 33% [severe MS] vs. 0% [control]). Similarly, there was a substantial impact on birth weight, which was reduced from 3,427 ± 426 g in the control patients to 2,706 ± 1,039 g (p = 0.02) in women with moderate MS and from 3,332 ± 403 g to 2,558 ± 947 g (p = 0.05) in cases with severe MS. Birth weight in women with mild MS was comparable to their control subjects (3,135 ± 419 g vs. 3,288 ± 531 g). A substantial increase in rate of premature birth was also reported by Silversides et al. (7). The rate of prematurity was 14% in patients with mild MS, 28% in patients with moderate MS, and 33% in patients with severe MS.

Treatment. The management of MS during gestation is more complex because of the potential impact on the fetus related to drug therapy and the exposure to ionizing radiation associated with diagnostic and therapeutic procedures such as cardiac catheterization or percutaneous balloon valvuloplasty, as well as the effect of anesthesia and cardiopulmonary bypass in the case of cardiac surgery (1). For clinicians treating women with MS, there are two separate groups of patients: the patients with MS who desire to become pregnant and are being evaluated before pregnancy and those who are already pregnant. Patients contemplating pregnancy who are found to have severe MS (mitral valve area [MVA] <1.0 cm²) should be offered percutaneous mitral balloon valvuloplasty (PMBV) before pregnancy. This approach will minimize or even completely prevent the anticipated clinical deterioration documented in such cases (6,7,18) and will reduce the need for pharmacologic or interventional therapy during pregnancy (18). The decision to perform PMBV before conception in patients with moderate MS should be on the basis of their MVA, symptoms, and exercise tolerance. Careful judgment is required in a patient with MS who is not a suitable candidate for PMBV. In such patients, especially those with moderate valvular stenosis who are either asymptomatic or mildly symptomatic, medical therapy during pregnancy may be preferred to mitral valve replacement before the pregnancy. With appropriate follow-up, patients with mild MS (MVA >1.5 cm²) usually have a favorable pregnancy outcome (6,7); valve repair before pregnancy, therefore, is not indicated.

Optimal management of the already pregnant patient with MS should aim at reducing the heart rate and left atrial pressure. Both heart rate and symptoms can be effectively controlled by restricting physical activity and administering beta-adrenergic receptor blockers (23), which are relatively safe and, in general, well tolerated by both the mother and the fetus (24). Use of beta-blockers with beta-1 adrenergic selectivity is preferred, because these agents would be less likely to interfere with beta-2-mediated uterine relaxation (24). Metoprolol may be preferred over atenolol, because the latter may be associated with a higher incidence of fetal growth retardation (25). Because of increased sympathetic activity during gestation, higher doses of beta-blockers are usually needed to achieve heart-rate control compared with the non-pregnant situation (26). In patients with atrial fibrillation, digoxin may also be useful as well as safe for control of ventricular rate (4). Because of one report indicating an increased incidence of major birth defects in newborns exposed to diltiazem during the first trimester, the use of verapamil is preferred when a calcium antagonist is indicated for heart-rate control during pregnancy (27). Left atrial pressure can also be reduced by a decrease in blood volume through restriction of salt intake and the use of oral diuretics. Aggressive use of diuretics, however, should be avoided to prevent hypovolemia and the reduction of uteroplacental perfusion (28).

MitrAL VALVE REPAIR DURING PREGNANCY. Although careful follow-up and medical therapy allow successful completion of pregnancy in the great majority of women (6,7,18–21), repair or replacement of the valve during pregnancy may be indicated in selected patients who remain symptomatic in spite of adequate medical therapy.

PBMV. The use of PBMV during pregnancy has been reported in an increasing number of patients, with over 300 cases described in recent years (29–37). Most reports include patients at the NYHA functional class III and IV who did not respond adequately to pharmacologic therapy. The procedure was performed in most cases at the end of the second trimester or the start of the third trimester, and in the majority of reported cases, hemodynamic and symp-
tomatic improvement was achieved. Mean MVA before the procedure ranged from 0.75 to 1.2 cm² and was increased after the procedure to a range of 1.7 to 2.2 cm². These results are similar to the results reported in the non-pregnant patients with MS (38). Reported rate of complications has been small, but included cardiac tamponade, excessive blood loss, transient atrial fibrillation, worsening of MR, systemic embolization, uterine contractions, and precipitous labor (29,31,35,39,40). In addition, PBMV is associated with some risk to the fetus secondary to unavoidable ionizing radiation (41). Although recent studies have reported normal growth and development of children born to women who underwent PBMV during pregnancy, the number of patients included in these studies was small and follow-up was limited to three to seven years (34,42–44). For this reason and to minimize risk to the fetus secondary to unavoidable ionizing radiation (41). Although recent studies have reported normal growth and development of children born to women who underwent PBMV during pregnancy, the number of patients included in these studies was small and follow-up was limited to three to seven years (34,42–44). For this reason and to minimize risk to the fetus, PBMV should be avoided if possible during the first trimester and should be performed by experienced operators with adequate abdominal and pelvic shielding with minimum radiation exposure (34,37). Exposure can be reduced by minimizing fluoroscopy and cine time and by using echocardiography and Doppler, instead, to obtain information on cardiac function and degree of MR (37). The use of the Inoue balloon catheter (Toray, Houston, Texas) seems to be preferred over a double-balloon technique, because it takes less time to perform and thus subjects the fetus to less radiation (45).

Should PBMV be performed prophylactically in asymptomatic or mildly symptomatic women with moderate or severe MS during pregnancy? Recent reports from North America have described 126 pregnancies in women with MS treated successfully without PBMV. Although these pregnancies were associated with no maternal mortality, a high incidence of maternal morbidity and compromised fetal outcome manifested by growth retardation, prematurity, and low birth weight was reported (6,7).

Because preterm birth and reduced fetal growth have been shown to be associated with an increased risk of infant morbidity and even mortality as well as incidence of adult hypertension, diabetes mellitus, and cardiovascular disease (46–49), prevention of preterm delivery seems to be a desirable therapeutic goal. Although some studies have indicated improved fetal outcome in women undergoing PBMV during pregnancy (50), other reports described a high incidence of prematurity, low birth weight, and fetal loss (3,32–34,51) in spite of the procedure and suggest that despite a significant hemodynamic and symptomatic improvement, the performance of PBMV at the second or third trimester of pregnancy may not prevent prematurity and occasional fetal death. On the basis of the available information, therefore, it seems reasonable to limit PBMV during pregnancy to symptomatic patients with severe MS who do not respond to medical therapy or who cannot be provided a close and expert follow-up during pregnancy, labor and delivery.

MITRAL VALVE SURGERY. A recent review (52) of the outcome of cardiovascular surgery in 161 pregnant women, of whom 59 were operated on for native valve disease, reported maternal mortality of 9% and fetal or neonatal mortality of 29%. Duration of pregnancy at time of surgery, length of cardiopulmonary bypass, and temperature did not influence fetal or neonatal outcome. These results have been recently confirmed by de Souza et al. (37), who compared the outcome of 21 patients with severe MS submitted to PMBV and 24 women who underwent open mitral valve commissurotomy during pregnancy and reported 38% fetal mortality in the surgical group, which occurred up to 24 h after the operation in 5 of 8 cases. Because of the high risk of what seems to be an unavoidable fetal loss, surgical mitral valve repair or replacement should be considered during pregnancy only in cases with severe MS who are refractory to optimal medical therapy and are not suitable candidates for PMBV or in cases where close follow-up during pregnancy is not possible.

MODE OF DELIVERY. Hameed et al. (6) reported vaginal delivery in 92% of 66 pregnancies in patients with VHD delivered between 1979 and 1998, 46 of whom had MS. Vaginal delivery with regional anesthesia was also the mode of delivery in 74% of cases reported by Silverside et al. (7), with assisted delivery in the second stage of labor in 20% of patients. Cesarean section was performed in 26% of the pregnancies, but only in 1 of 21 cases for maternal cardiac reasons. Similarly, Bhatla et al. (18) reported a 20% rate of cesarean section in a group of 205 patients with cardiac disease, of whom 71 had MS; cesarean section was performed in all cases for obstetric indications. This information clearly shows that vaginal delivery can be permitted in most patients with MS, including those with severe stenosis, whereas cesarean section is indicated mostly for obstetric indications. The second stage of labor should be shortened by the use of outlet forceps or vacuum extractor (1). Epidural anesthesia is recommended for pain relief (53) and has been shown to minimize intrapartum fluctuations in cardiac output (54) and to lower left atrial and pulmonary artery pressures (55). Hypotension, the primary complication of epidural analgesia, can be avoided or treated by left uterine displacement and careful infusion of crystalloid and vasoconstrictors, without a chronotropic effect. Hemodynamic monitoring during labor and delivery with a pulmonary artery catheter is recommended in all patients with moderate and severe MS (55). Optimization of left atrial pressure before delivery may be needed and can be achieved by diuresis and reduction of heart rate with beta-blockers. Increased venous return in the early puerperium may result in a marked increase in left atrial and pulmonary pressure (56) and can lead to the development of pulmonary edema (6,7,18). For this reason, hemodynamic monitoring should continue for 12 to 24 h after the delivery. The use of tocolytic agents with beta-mimetic effect is contraindicated.
in patients with MS because of their strong chronotropic effect (57), and the use of magnesium sulfate, which has negligible hemodynamic effect, is preferred.

MR. Mitral regurgitation during pregnancy is usually due to rheumatic valvular disease or mitral valve prolapse (6,18,20). Because of the significant fall in systemic vascular resistance during pregnancy and reduced left ventricular afterload (9), MR is well tolerated even if severe. For the patient with MR who is contemplating pregnancy, but is not considered a candidate for surgical mitral valve repair or replacement on the basis of usual clinical indications (58), prophylactic surgery should not be done, because pregnancy after valve replacement may be less desirable. Asymptomatic patients do not require therapy during pregnancy, and the treatment of patients with left ventricular dysfunction who develop hemodynamic abnormalities and symptoms of heart failure can include the use of diuretics and digoxin. Because angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor antagonists are contraindicated during pregnancy (59), organic nitrates and hydralazine can be used for vasodilatation. Because of the high incidence of fetal loss (52), surgery for mitral valve repair or replacement should be avoided if possible during pregnancy and considered only in patients with severe symptoms not controlled by medical therapy.

Aortic stenosis. Aortic stenosis (AS) during pregnancy is mostly due to congenital etiology (2). Rheumatic AS is less common and occurs in conjunction with mitral valve disease in approximately 5% of pregnant women with rheumatic valvular disease (1,6,18). Cases with subvalvular and supra-valvular AS have also been described in pregnancy (60,61). Most patients with mild and moderate AS have a favorable outcome of pregnancy (6,61); at the same time, however, the presence of severe AS may result in hemodynamic and symptomatic deterioration with the development of heart failure, leading to hospitalizations and premature delivery. Silverside et al. (61) recently reported on 49 pregnancies in women with severe AS reported in the above two studies (6,61). This patient had severe AS in addition to a coarctation of the aorta and died in conjunction with aortic valve replacement 10 days after a successful abdominal delivery.

In summary, most patients with AS, especially those with valve area >1.0 cm², tolerate pregnancy well, provided early diagnosis and close follow-up. Severe AS can be associated with important maternal morbidity and unfavorable fetal outcome, but maternal mortality is rare. In addition, a high rate of expected cardiac surgery after the pregnancy in women with severe AS should be taken into account and explained to the patients at the time of pre-pregnancy counseling (61). Ideally, women with severe AS should undergo either balloon valvuloplasty, if appropriate, or valve replacement before pregnancy. The medical treatment in symptomatic patients with AS during gestation is limited to diuretics. Patients who develop severe symptoms during pregnancy, but are resistant to medical therapy and cannot be delivered, may require early termination of pregnancy (60) or repair of the valve either by percutaneous balloon valvuloplasty (61–63) or surgery (64). Because balloon valvuloplasty seems to be associated with a smaller risk of fetal loss compared with surgical replacement (52), valvuloplasty is preferred when possible. Both interventions carry risk to the fetus (radiation with valvuloplasty and fetal loss with surgery), and complaints related to pregnancy itself can mimic cardiac disease; therefore, symptoms should be carefully evaluated before the decision to perform these procedures is made. When intervention seems to be indicated and fetal maturity can be confirmed, the patient should be delivered first and valve repair or replacement should be performed after delivery if possible. Hemodynamic monitoring is strongly recommended for labor and delivery in patients with moderate and severe AS. The preferred mode of delivery is vaginal with assisted second stage of labor. Vaginal delivery was performed successfully in 67% of 49 pregnancies in women with AS reported by Silversides et al. (61); two-thirds of these patients had labor induced. Cesarean delivery was performed in 33% of the patients, but only in one case due to maternal cardiac indication. Regional anesthesia for labor and delivery should be used with caution in patients with AS to prevent a decrease in systemic vascular resistance that may be poorly tolerated, and general anesthesia remains the preferred technique for cesarean section in patients with AS (53).
Aortic regurgitation. Aortic regurgitation (AR) in young women may be due to congenital bicuspid valve (2,61), rheumatic disease (6), endocarditis (65), or dilated aortic annulus (66). Similar to MR, AR without left ventricular dysfunction is usually well tolerated during pregnancy, probably secondary to a marked fall in systemic vascular resistance and possibly due to the physiological increase in heart rate which may shorten diastolic and thus reduce degree of regurgitation (9). In cases of severe AR and left ventricular dysfunction that are symptomatic, medical therapy can include salt restriction, diuretics, and digoxin. The vasodilators hydralazine and nitrates can be used as a substitute to ACE inhibitors, which are contraindicated during pregnancy (59). Surgery, if indicated, should be delayed if possible until after the delivery to avoid the high risk of fetal loss (52). Symptomatic patients and patients with left ventricular dysfunction should benefit from hemodynamic monitoring during labor and delivery. Asymptomatic patients with severe AR, but normal left ventricular function who contemplate pregnancy and are not considered candidates for valve replacement on the basis of established indications (58) will do well and should not have prophylactic valve surgery before pregnancy.

Pulmonic stenosis. Isolated pulmonic stenosis (PS) during pregnancy is most commonly due to a congenital obstruction at the valvular level but can also occur at the subvalvular or supravalvular level and as a consequence of deterioration of a homograft inserted as part of the Ross procedure (2,67).

Isolated valvular PS, even when severe, is usually well tolerated during pregnancy. An early study by Nielson et al. (68) reported on 26 pregnancies in 11 patients with PS. There were four spontaneous abortions, one in a patient with severe PS who had right heart failure during the first pregnancy but then had three additional uneventful pregnancies after valvotomy. More recently, Hameed et al. (69) reported the outcome of pregnancy in 17 patients with PS from 1995 to 2003. Eleven patients were in NYHA functional class I, and six in class II at the time of presentation. All patients remained stable during pregnancy except one who deteriorated from class I to III early during pregnancy, but then improved to class II as pregnancy progressed. There was no difference between patients and their matched control subjects in duration of pregnancy (38.4 ± 1.9 weeks vs. 39.3 ± 1.2 weeks, p = 0.07), birth weight (3,278 ± 474 g vs. 3,360 ± 432 g, p = 0.83), or placental weight (648 ± 184 g vs. 693 ± 421 g, p = 0.83). Average Apgar scores at one min and five min were nine for each group. A comparison between patients with severe PS (peak gradient across the value >50 mm Hg with a mean of 82 ± 28 mm Hg) and those with milder PS (mean gradient 34 ± 11 mm Hg) revealed no difference in any of the studied parameters. In spite of the limited number of patients with PS reported, the available information indicates that pregnancy in patients with PS is tolerated well and that, in contrast to MS and AS, the severity of PS does not adversely impact maternal or fetal outcome. Balloon valvuloplasty is recommended in non-pregnant patients when the gradient across the right ventricular outflow track is >50 mm Hg at rest (70) or when the patient is symptomatic. Such a procedure, however, is rarely indicated during pregnancy in patients who are either asymptomatic or mildly symptomatic before pregnancy. Vaginal delivery is tolerated well and can be permitted in the great majority of patients with PS.

Reprint requests and correspondence: Dr. Uri Elkayam, Heart Failure Program, Keck School of Medicine, Los Angeles County/University of Southern California Medical Center, Room 7621, 1200 North State Street, Los Angeles, California 90033. E-mail: elkayam@usc.edu.

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