Pregnancy Outcomes in Women With Congenital Heart Disease

Paul Khairy, MD, PhD; David W. Ouyang, MD; Susan M. Fernandes, MPH, PA-C; Aviva Lee-Parritz, MD; Katherine E. Economy, MD; Michael J. Landzberg, MD

Background—Pregnant women with congenital heart disease are at increased risk for cardiac and neonatal complications, yet risk factors for adverse outcomes are not fully defined.

Methods and Results—Between January 1998 and September 2004, 90 pregnancies at age 27.7±6.1 years were followed in 53 women with congenital heart disease. Spontaneous abortions occurred in 11 pregnancies at 10.8±3.7 weeks, and 7 underwent elective pregnancy termination. There were no maternal deaths. Primary maternal cardiac events complicated 19.4% of ongoing pregnancies, with pulmonary edema in 16.7% and sustained arrhythmias in 2.8%. Univariate risk factors included prior history of heart failure (odds ratio [OR], 15.5), NYHA functional class ≥2 (OR, 5.4), and decreased subpulmonary ventricular ejection fraction (OR, 7.7). Independent predictors were decreased subpulmonary ventricular ejection fraction and/or severe pulmonary regurgitation (OR, 9.0) and smoking history (OR, 27.2). Adverse neonatal outcomes occurred in 27.8% of ongoing pregnancies and included preterm delivery (20.8%), small for gestational age (8.3%), respiratory distress syndrome (8.3%), intraventricular hemorrhage (1.4%), intrapartum fetal demise (2.8%), and neonatal death (1.4%). A subaortic ventricular outflow tract gradient >30 mm Hg independently predicted an adverse neonatal outcome (OR, 7.5). Cardiac risk assessment was improved by including decreased subpulmonary ventricular systolic function and/or severe pulmonary regurgitation (OR, 10.3) in a previously proposed risk index developed in pregnant women with acquired and congenital heart disease.

Conclusions—Maternal cardiac and neonatal complication rates are considerable in pregnant women with congenital heart disease. Patients with impaired subpulmonary ventricular systolic function and/or severe pulmonary regurgitation are at increased risk for adverse cardiac outcomes. (Circulation. 2006;113:517-524.)

Key Words: arrhythmia ■ heart defects, congenital ■ pregnancy ■ tetralogy of Fallot ■ transposition of great vessels

Recent advances in pediatric cardiology and cardiac surgery have enabled increasing numbers of women with congenital heart disease to thrive well into their childbearing years. Although maternal deaths in pregnant women with congenital heart disease are rarely reported, maternal cardiac and neonatal complications are considerable. Prior studies either have focused on outcomes in women with particular congenital defects or have encompassed all forms of heart disease, including ischemic, hypotrophic, and dilated cardiomyopathies, acquired valve disease, and arrhythmias in women with structurally normal hearts. Proposed risk assessment algorithms derived from such studies have provided valuable information but are not specific to the congenital heart population and may be heavily weighted toward acquired forms of heart disease. We therefore sought to assess outcomes and determine risk factors for adverse maternal and neonatal events in a contemporary cohort of pregnant women exclusively with congenital heart disease.

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Study Design

The study cohort consisted of all women with congenital heart disease followed by the Boston Adult Congenital Heart (BACH) service and delivering at Brigham and Women’s Hospital between January 1998 and September 2004. Women with acquired heart disease, primary arrhythmia diagnoses without underlying congenital defects, and isolated mitral valve prolapse were excluded. Baseline data collected before pregnancy or at the first prenatal visit were retrospectively recorded from electronic and paper obstetric, cardiological, surgical, echocardiographic, and radiographic charts and databases supplemented by records from referring physicians. Variables included age, height, weight, ethnicity, educational and marital status, cigarette and/or alcohol consumption, medications, obstetric history, medical history (eg, diabetes, pulmonary disease, systemic and/or pulmonary thromboembolic disease), cardiac diagnoses and surgical procedures, prior cardiac history (eg,
heart failure, endocarditis, arrhythmia), New York Heart Association (NYHA) functional class, blood pressure, heart rate, oxygen saturation, maximum oxygen uptake (mL/kg per minute), laboratory values (eg, blood urea nitrogen, creatinine, hematocrit), echocardiographic assessment including Doppler quantification of obstructive and regurgitant lesions and systolic pulmonary artery pressure estimates, and cardiac MRI findings. Follow-up data were obtained from clinical visits throughout pregnancy and the puerperium and included changes in medication, NYHA functional class, provision of high-risk care, onset of cardiac care, and formal genetic counseling.

Cardiac, obstetric, and neonatal events were classified according to previously proposed definitions determined by Siu and colleagues.4 Cardiac complications were subdivided into primary and secondary events. A primary cardiac event consisted of cardiac death, cardiac arrest, stroke, symptomatic sustained bradycardia or tachyarrhythmia requiring therapy, or pulmonary edema documented by physical examination or radiography. Decline in ≥2 NYHA functional classes, need for urgent invasive cardiac interventions during pregnancy or within 6 weeks postpartum, and symptomatic nonsustained bradycardia or tachyarrhythmia requiring therapy were considered secondary cardiac events. Obstetric events consisted of preeclampsia, defined as sustained systolic or diastolic blood pressure ≥140 or ≥90 mm Hg, respectively, with concomitant proteinuria; postpartum hemorrhage, defined as estimated blood loss >500 mL for vaginal delivery or >1 L for cesarean delivery accompanied by a ≥10 g/L drop in hemoglobin or requiring transfusion; and noncardiac death. Neonatal events were defined as perinatal delivery (<37 weeks of gestation), birth weight small for gestational age (<10th percentile), respiratory distress syndrome, cerebral intraventricular hemorrhage, fetal death (≥20 weeks of gestation), or neonatal death (within the first month after birth). Spontaneous abortion was defined as fetal loss before 20 weeks of gestation. The protocol was approved by the institutional review boards of both hospitals. The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

The validity of a previously proposed maternal cardiac risk index from the Cardiac Disease in Pregnancy (CARPREG) investigators,4 generated in a cohort of women with a variety of congenital and acquired forms of heart disease, was tested in the study population. One point was assigned for each of the following variables: arrhythmia or prior cardiac event (heart failure, transient ischemic attack, or stroke before pregnancy); baseline NYHA functional class III or IV or cyanosis (oxygen saturation <90%); systemic heart obstruction (atrioventricular valve area of the subaortic ventricle <2 cm², aortic valve area <1.5 cm², or peak outflow tract gradient of the subaortic ventricle >30 mm Hg); and subaortic ventricular ejection fraction <40%.

**Statistical Analyses**
Dichotomous variables are presented as percentage and continuous variables as mean±SD or median and range depending on their data structure. Generalized estimating equations were used to produce regression marginal models for cluster sampling data by specifying link and distribution functions. Univariate and multivariate predictors of cardiovascular, neonatal, and obstetric events were assessed. Highly correlated (r≥0.6) statistically significant univariate predictors were combined for consideration in multivariable models. In validating the previously proposed CARPREG index, actual versus expected primary cardiac event rates were compared by χ² goodness-of-fit tests. A generalized estimating equation model that controlled for the CARPREG index assessed the additional predictive ability of candidate risk factors for adverse maternal cardiac risk. Two-tailed probability values <0.05 were considered statistically significant. Statistical testing was performed with the use of SAS software Version 8 (SAS Institute).

**Results**

**Baseline Characteristics**
During the study period, 614 women with congenital heart disease between 12 and 50 years of age were seen in the outpatient division of the BACH service. Of these women, 53 had a total of 90 pregnancies at age 27.7±6.1 years. Underlying congenital heart lesions and maternal baseline characteristics are summarized in Tables 1 and 2, respectively. Gestational age at the first prenatal visit was 12.8±7.9 weeks. Overall, 41% of pregnancies were considered planned. Genetic counseling was received in 26%, cardiology counseling before pregnancy in 71%, and high-risk obstetric care in 92%.

Complete information on cardiac and obstetric events was available for all pregnancies, and 98% of pregnancies had complete information on neonatal events. Echocardiographic data were available in 92% of pregnancies, and cardiac MRI findings were available in 11%. When both were performed, the degree of atrioventricular and aortic regurgitation, subaortic ventricular function, and subaortic

<table>
<thead>
<tr>
<th>TABLE 1. Distribution by Primary Type of Congenital Heart Disease</th>
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<tbody>
<tr>
<td><strong>Congenital Lesion</strong></td>
</tr>
<tr>
<td>Septal defect</td>
</tr>
<tr>
<td>Atrial septal defect</td>
</tr>
<tr>
<td>Unoperated</td>
</tr>
<tr>
<td>Surgically repaired</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
</tr>
<tr>
<td>Unoperated</td>
</tr>
<tr>
<td>Surgically repaired</td>
</tr>
<tr>
<td>Surgically repaired atrioventricular canal defect</td>
</tr>
<tr>
<td>Right-sided obstructive lesion</td>
</tr>
<tr>
<td>Pulmonary stenosis, unoperated</td>
</tr>
<tr>
<td>Pulmonary stenosis with surgical valvotomy</td>
</tr>
<tr>
<td>Pulmonary atresia, ventricular septal defect, and RV-PA conduit</td>
</tr>
<tr>
<td>Left-sided obstructive lesion</td>
</tr>
<tr>
<td>Aortic stenosis</td>
</tr>
<tr>
<td>Unoperated (excluding patent ductus arteriosus ligation)†</td>
</tr>
<tr>
<td>Transtracheal valvuloplasty</td>
</tr>
<tr>
<td>Aortic valve replacement with coarctation repair</td>
</tr>
<tr>
<td>Surgically repaired aortic coarctation</td>
</tr>
<tr>
<td>Tetralogy of Fallot after repair</td>
</tr>
<tr>
<td>TGA</td>
</tr>
<tr>
<td>D-TGA with Mustard or Senning</td>
</tr>
<tr>
<td>D-TGA, ventricular septal defect, pulmonary stenosis with Rastelli</td>
</tr>
<tr>
<td>Unoperated congenitally corrected TGA</td>
</tr>
<tr>
<td>Single ventricle with Fontan physiology</td>
</tr>
<tr>
<td>Ebstein’s anomaly</td>
</tr>
<tr>
<td>Repaired anomalous left coronary artery from pulmonary artery</td>
</tr>
</tbody>
</table>

RV-PA indicates right ventricle to pulmonary artery; TGA, transposition of the great arteries.

†Aortic stenosis gradient of 30 mm Hg.

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ventricular outflow tract obstruction were concordant in all cases. Pulmonary regurgitation was graded severe by echocardiography and mild by MRI in one patient and moderate by echocardiography and severe by MRI in another. In a third patient, subpulmonary ventricular systolic function was deemed normal by echocardiography and mildly dysfunctional by cardiac MRI. In all cases of discrepancy, MRI data were retained.

Cardiac Events
Qualifying cardiac events occurred in 25.0% of ongoing pregnancies and were limited to heart failure with pulmonary edema, symptomatic arrhythmias, and need for urgent invasive intervention (Table 3). Predictors of primary cardiac events are summarized in Table 4. There were no maternal deaths. Four patients experienced deterioration by 1 NYHA functional class. One patient with Turner syndrome, surgically repaired aortic coarctation, and normal biventricular systolic function had a troponin leak in the setting of preeclampsia with hemolysis, elevated liver enzymes, and low platelets (HELLP) syndrome.12 She had invasive monitoring to assist with volume management during hospitalization.

The most common adverse cardiac event was pulmonary edema, documented in 12 pregnancies. Underlying con-
genital cardiac diagnoses were as follows: tetralogy of Fallot (n=5) with severe pulmonary regurgitation in all and subpulmonary ventricular systolic dysfunction in 3 patients, 1 of whom had biventricular systolic dysfunction; transposition of the great arteries (n=2) with a Mustard (n=1) or Senning (n=1) baffle; bicuspid aortic valve with mixed aortic valve disease (n=2), 1 of whom had aortic valve replacement; bicuspid aortic valve with surgically corrected aortic coarctation (n=2), 1 of whom had concomitant surgery for a supravalvar mitral ring; and surgically repaired primum atrial septal defect and cleft mitral valve (n=1). All episodes of heart failure responded to medical therapy that included diuretics, except for the patient with mixed aortic valve disease and increasing aortic stenosis (gradient >100 mm Hg) who underwent urgent aortic valve replacement at 20 weeks of gestation. Intrauterine fetal demise occurred on the third postoperative day.

Symptomatic arrhythmias were documented in 8 pregnancies, 2 of which were supraventricular and sustained. A patient with a Rastelli repair was cardioverted for atrial flutter, and a patient with a stenotic bicuspid aortic valve was successfully treated medically for supraventricular tachycardia. Six patients had palpitations with documented nonsustained monomorphic ventricular tachycardia. A patient with repaired tetralogy of Fallot had a 17-beat run of ventricular tachycardia on Holter monitoring requested for palpitations and dizziness. Sustained ventricular tachycardia was not inducible on an electrophysiological study at 22 weeks of gestation, and β-blocker therapy was initiated. One patient with pulmonary atresia and right ventricle to pulmonary artery conduit had an 18-beat run of ventricular tachycardia on Holter monitoring but refused medical therapy. Four other patients had 4- to 10-beat runs of ventricular tachycardia treated with β-blockers. Underlying congenital lesions were tetralogy of Fallot (n=1), pulmonary stenosis and atrial septal defect (n=1), transposition of the great arteries with a Mustard baffle (n=1), and hypoplastic right ventricle with a modified Fontan (n=1).

In further analyses of independent risk factors for primary or secondary cardiac events, smoking was associated with pulmonary edema (odds ratio [OR], 9.5; 95% CI, 1.8 to 50.5; P=0.0082) and symptomatic arrhythmias (OR, 9.0; 95% CI, 1.6 to 52.0; P=0.0140). Similarly, subpulmonary ventricular dysfunction and/or severe pulmonary regurgitation was predictive of both symptomatic arrhythmias (OR, 6.9; 95% CI, 1.1 to 42.1; P=0.0358) and pulmonary edema (OR, 4.6; 95% CI, 1.2 to 17.9; P=0.0283). This latter association persisted after adjustment for subaortic ventricular systolic dysfunction (OR, 4.1; 95% CI, 1.0 to 16.1; P=0.0486).

### Obstetric and Neonatal Events

Eighteen pregnancies (20.0%) were aborted: 11 (12.2%) spontaneously and 7 (7.8%) electively. Nine spontaneous abortions occurred in the first trimester and 2 in the second trimester, at a mean of 10.8±3.7 weeks. Univariate predictors of spontaneous abortion were maternal hypertension (OR, 17.8; 95% CI, 1.4 to 218.3; P=0.0247), antiplatelet agent (OR, 7.3; 95% CI, 1.6 to 33.4; P=0.0100), and antiarrhythmic medication (OR, 5.3; 95% CI, 1.2 to 23.0; P=0.0249). All ongoing 72 pregnancies were singletons except for 1 twin pregnancy. There were 2 intrauterine fetal demises occurring at 20 and 26 weeks of gestation. The demise at 20 weeks of gestation is described above. The other took place in a patient with a stenotic bicuspid aortic valve whose pregnancy was complicated by ovarian vein thrombosis and pulmonary embolism. The only neonatal death also occurred in this patient’s prior pregnancy. That pregnancy was complicated by premature rupture of membranes at 24.5 weeks of gestation requiring urgent cesarean delivery for chorioamnionitis. The neonate expired 9 days after delivery from complications of prematurity. Seventeen pregnancies (23.6%) were delivered by cesarean, and 55 (76.4%) had successful vaginal deliveries. All

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**TABLE 4. Maternal Predictors of Primary Cardiac Events During Pregnancy**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>Baseline NYHA class ≥2</td>
<td>5.4</td>
<td>1.2, 25.2</td>
<td>0.0320</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>1.1</td>
<td>1.02, 1.14</td>
<td>0.0098</td>
</tr>
<tr>
<td>Prior history of heart failure</td>
<td>15.5</td>
<td>1.5, 163.6</td>
<td>0.0223</td>
</tr>
<tr>
<td>Smoking history</td>
<td>15.6</td>
<td>2.6, 92.7</td>
<td>0.0026</td>
</tr>
<tr>
<td>Pulmonary regurgitation</td>
<td>1.8</td>
<td>1.1, 3.1</td>
<td>0.0440</td>
</tr>
<tr>
<td>Severe pulmonary regurgitation</td>
<td>4.6</td>
<td>1.1, 19.5</td>
<td>0.0372</td>
</tr>
<tr>
<td>Depressed subpulmonary ventricular EF</td>
<td>7.7</td>
<td>1.5, 40.2</td>
<td>0.0159</td>
</tr>
<tr>
<td>Depressed morphological right ventricular EF</td>
<td>4.6</td>
<td>1.4, 15.2</td>
<td>0.0130</td>
</tr>
<tr>
<td>Smoking history</td>
<td>27.2</td>
<td>1.9, 384.6</td>
<td>0.0145</td>
</tr>
</tbody>
</table>

EF indicates ejection fraction.
patients without an obstetric contraindication attempted a trial of labor. All but 1 patient received epidural anesthesia, and all labored primarily in the left lateral decubitus position. Twenty vaginal deliveries were spontaneous, whereas 35 were assisted by forceps (n=22) or vacuum (n=13). All cesarean deliveries were performed for routine obstetric indications: breech (n=5), elective repeated cesarean (n=3), cephalopelvic disproportion (n=3), and other (n=6). Obstetric and neonatal events are summarized in Table 3, and predictors of neonatal events are summarized in Table 5.

Of the 70 live births, the following cardiac anomalies were diagnosed in 5 progeny (7.1%): tetralogy of Fallot, ventricular septal defect, dilated cardiomyopathy, cor triatriatum, and interrupted aortic arch with ventricular septal defect. All cases were identified by fetal cardiac ultrasonography before birth. Additional congenital malformations included single umbilical artery, anomalous left subclavian artery, and gonadal dysgenesis.

Validation of Cardiac Risk Index
Actual versus predicted primary cardiac event rates in patients with 0, 1, and ≥2 predictors from the previously proposed CARPREG risk index were 12%, 30%, and 100% versus 5%, 27%, and 75%, respectively. Differences between actual and predicted rates, depicted in the Figure, panel A, were not statistically significant (P=0.5904). Further stratification according to whether or not patients had severe pulmonary regurgitation and/or reduced subpulmonary ventricular systolic function further improved overall risk assessment (P=0.0111). As illustrated in the Figure, panel B, this was most marked in patients with 1 predictor (83% versus 8%; P=0.0010). In a multiple regression model that controlled for the CARPREG index score, smoking history (OR, 19.3; 95% CI, 2.6 to 146.3; P=0.0041) and subpulmonary ventricular dysfunction and/or severe pulmonary regurgitation (OR, 10.3; 95% CI, 1.9 to 55.9; P=0.0069) had independent predictive ability. A 1-point increase in the CARPREG index was associated with a 5-fold increased risk for maternal cardiac complications (OR, 5.1; 95% CI, 1.4 to 18.1; P=0.0113).

Discussion
As an increasing number of women with congenital heart disease contemplate pregnancy, caregivers are faced with the difficult task of estimating maternal and fetal risks to counsel patients regarding safety issues and plan antenatal care. In the absence of clear data, recommendations are often based on comprehensive clinical assessments with speculations as to how particular underlying cardiac substrates are likely to respond to physiological changes imposed by pregnancy. This study examines a large contemporary cohort of pregnancies in women exclusively with congenital heart disease.

The spontaneous abortion rate of 12.2% of clinically recognized pregnancies is likely underestimated because those occurring before medical attention and referral are not tabulated. Nevertheless, this rate is consistent with those described in women without heart malformations, in whom the incidence of miscarriage is 12% to 15% for clinical pregnancies and 17% to 22% if early pregnancy abortion is included.
losses are included. Associations between miscarriages, hypertension, and aspirin have been previously reported. Class III antiarrhythmic agents such as sotalol have been shown to increase the incidence of embryonic deaths in animal studies. Of live offspring, the 7% rate of cardiac anomalies is identical to a previously reported recurrence rate in mothers with congenital heart disease and 10-fold higher than the population at large.

The primary cardiac event rate of 19.4% observed in this study is comparable to the 23.5% incidence described in a large cohort of pregnant women with heart disease, of whom 19.1% had underlying congenital heart malformations. The remaining patients had rheumatic heart disease (55.7%), Chagas’ disease (8.5%), cardiac arrhythmias (5.1%), cardiomyopathies (4.3%), and others (7.3%). In a prospective multicenter study of pregnancy outcomes in women with heart disease, Siu et al reported a 13% incidence of primary cardiac events. This lower event rate may be explained in part by differences in study populations because 22% of women had acquired forms of heart disease and 4% had structurally normal hearts with arrhythmias. In addition, lower-risk patients are less likely to be referred to a tertiary care center.

As in the present study, the most common cardiac complications have consistently been congestive heart failure followed by arrhythmias. Responses to medical therapy have generally been favorable. Among risk factors for adverse cardiac outcomes, advanced NYHA functional class and prior history of heart failure have been previously described. Detrimental effects of smoking on cardiovascular hemodynamics are well known and include increases in heart rate, systemic vascular resistance, systemic arteriolar resistance, blood pressure, pulmonary artery pressure, pulmonary vascular resistance, right and left atrial pressures, and arrhythmias. In addition to previously described risk factors, the present study found an increased incidence of adverse cardiac events in pregnant women with depressed subpulmonary ventricular ejection fraction and/or severe pulmonary regurgitation. Perhaps these risk factors were not previously identified because of the strong influence of acquired forms of heart disease on risk factor identification. In CARPREG, a notable 69% of heart failure events occurred in patients with acquired valve disease or noncongenital cardiomyopathy.

Neonatal complications occurred in 27.8% of pregnancies, comparable to the 20% reported in CARPREG. In both studies, premature births were the most common events, followed by birth weight small for gestational age and respiratory distress syndrome. Identified risk factors including smoking during pregnancy, cyanosis, and maternal systemic heart obstruction were similar in both studies.

When differences in study populations are considered, on the whole, our findings are consistent with prior reports of risk factors in women with congenital and other forms of heart disease. In fact, the CARPREG index had independent predictive value, providing further validation of this risk score. However, in women exclusively with congenital heart disease, risk stratification could be refined by considering the presence of severe pulmonary regurgitation and/or impaired subpulmonary ventricular function. This finding is further supported by a recent study in pregnant women with tetralogy of Fallot in whom 5 of 6 patients with adverse cardiovascular events had hemodynamically significant lesions including severe pulmonary regurgitation with subpulmonary ventricular dysfunction, severe pulmonary hypertension with marked subpulmonary ventricular dilation, subpulmonary ventricular hypertension due to hypoplastic pulmonary arteries, and peri-partum subaortic ventricular dysfunction.

During the course of pregnancy, hormonally mediated changes result in an increase in blood volume, red blood cell mass, and heart rate. Systolic subaortic ventricular function decreases near term and early postpartum because of reduced contractility and decreased preload. Interestingly, different degrees of chamber enlargement in systemic and pulmonary circulations have been observed. Whereas subaortic ventricular size increases by 6%, the right atrium and subpulmonary ventricle increase by 20%. Morphological characteristics of an already compromised subpulmonary ventricle may enhance susceptibility to further pregnancy-induced volume loading. Moreover, the additional volume load on a subpulmonary ventricle exposed to hemodynamic or hypoxic stress and surgical scars may predispose to such cardiac complications as atrial or ventricular arrhythmias. Indeed, the association between ventricular arrhythmias and severe pulmonary regurgitation with subpulmonary ventricular dilation is well established in patients with repaired tetralogy of Fallot.

In our study, pulmonary edema complicating pregnancy was associated with subpulmonary ventricular dysfunction and/or severe pulmonary regurgitation independent of subaortic ventricular systolic function. Previously demonstrated right to left ventricular interactions may be amplified in congenitally malformed hearts. Whereas deeper myocardial fiber layers are separated, superficial layers encircling normal right and left ventricles are shared. In some malformations, even deeper layers of right and left ventricles may be contiguous within the interventricular septum. In experimental studies, gradual enlargement of a noncontractile right ventricular free wall resulted in progressive reduction in left ventricular mechanical work. Moreover, right ventricular volumes may modulate left ventricular indices of diastolic contractility. Acute right ventricular dilation, even in the absence of an intact pericardium, is associated with substantial reductions in load-independent measures of left ventricular myocardial contractility. These changes could not be explained by alterations in left ventricular geometry and likely reflect abnormalities of myocardial “cross talk.”

**Limitations**

Data were retrospectively collected. Follow-up, outcome assessment, and treatment strategies were not standardized. However, information bias was likely minimized by the completeness of data, absence of losses to follow-up, and uniformity of obstetric and cardiology caregivers from a
single center. In addition, patients at low or negligible risk may not have been referred to a regional center, and those deemed at highest risk may have been counseled against pregnancy. For example, only 2 patients in this cohort had a primary diagnosis of secundum atrial septal defect, and no patient had cyanosis, a NYHA functional class of III or IV, or more than mild subaortic ventricular dysfunction.

**Conclusion**

In a large single-center cohort of pregnant women with congenital heart disease, maternal cardiac and neonatal complications were considerable. Patients with impaired subpulmonary ventricular systolic function and/or severe pulmonary regurgitation are at increased risk for adverse cardiac outcomes. Despite this high maternal cardiac complication rate, with careful surveillance and prompt recognition of symptoms, an overall favorable response to therapy was noted, with no maternal deaths. A multidisciplinary approach that includes availability of high-risk obstetric care, specialized cardiology assessment and follow-up, and genetic counseling is recommended for women with congenital heart disease contemplating pregnancy.

**Acknowledgments**

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**Disclosures**

None.

**References**

CLINICAL PERSPECTIVE

Risk factors for adverse outcomes in pregnant women with congenital heart disease have not been fully defined. In a cohort study of 90 pregnancies in 53 women exclusively with congenital heart disease, major adverse cardiac events (ie, heart failure or sustained arrhythmias) complicated nearly 1 in 5 pregnancies. Women with a smoking history were much likely to suffer cardiac complications. Moreover, women with a decreased subpulmonary ventricular ejection fraction and/or severe pulmonary regurgitation were 9 times more likely to develop heart failure or sustained arrhythmias during pregnancy. Incorporating this parameter into a previously proposed risk stratification scheme provided predictive value above and beyond known risk factors. Despite the high rate of cardiac complications, there were no maternal deaths. Adverse neonatal outcomes occurred in >25% of ongoing pregnancies and included preterm delivery (20.8%), small for gestational age (8.3%), respiratory distress syndrome (8.3%), intraventricular hemorrhage (1.4%), intrauterine fetal demise (2.8%), and neonatal death (1.4%). A subaortic ventricular outflow tract gradient >30 mm Hg independently predicted such adverse neonatal outcomes. In conclusion, maternal cardiac and neonatal complication rates are considerable in pregnant women with congenital heart disease. However, with careful surveillance and prompt recognition of symptoms, an overall favorable response to therapy is noted. A multidisciplinary approach that includes availability of high-risk obstetric care, specialized cardiology assessment and follow-up, and genetic counseling is recommended for women with congenital heart disease contemplating pregnancy.
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