Perioperative management and outcomes of aortic surgery during pregnancy

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Objective: Pathology of the aortic valve and ascending thoracic aorta is an uncommon but life-threatening complication of pregnancy. Cardiac surgery during pregnancy is known to carry a high risk of mortality to both the mother and fetus. We present our experience of performing aortic surgery during the patients' pregnancy.

Methods: All patients undergoing aortic surgery during pregnancy at St George's Hospital, from January 2004 until October 2013, were identified. Surgery was performed using cardiopulmonary bypass at 36°C, with pulsatile perfusion at 70 mm Hg. Fetal blood flow parameters were serially monitored during surgery, via transabdominal and/or transvaginal Doppler ultrasonography. Surgery was performed in the second trimester when possible to allow completion of organogenesis and minimize hemodynamic compromise.

Results: Eleven patients underwent aortic surgery. The median age was 28 years (range, 26-31 years), with gestational age 19 weeks (range, 16-21 weeks). Six patients had aortic root dilatation with aortic regurgitation, and 5 had aortic stenosis, one of whom presented with acute type A dissection. Four patients had Marfan syndrome, and 2 had undergone previous cardiac surgery. The operative procedures were aortic root replacement (tissue valve, $n = 5$; homograft, $n = 1$), aortic valve replacement ($n = 3$), valve-sparing root replacement ($n = 1$), and aortic and mitral valve replacements ($n = 1$). Mean cardiopulmonary bypass and cross-clamp times were 105 and 89 minutes, respectively. There were no maternal deaths; 8 healthy babies were born at term, and 3 pregnancies resulted in intrauterine demise within 1 week of surgery.

Conclusions: Major aortic surgery during pregnancy carries a high risk to both mother and baby. With appropriate maternal and fetal monitoring, attention to cardiopulmonary bypass, pulsatile perfusion, near-normothermia, and avoidance of vasoconstrictors, these risks may be minimized. (J Thorac Cardiovasc Surg 2015;149:607-10)

See related commentary on pages 611-2.

Heart disease is present in only 1% to 2% of pregnant women; however, it accounts for 10% to 15% of all maternal deaths.¹ Pathology of the aortic valve and the ascending thoracic aorta is an uncommon but life-threatening complication of pregnancy. Patients with known significant disease of their aortic valve or ascending thoracic aorta should be counseled before pregnancy regarding treatment of their condition. However, if patients are asymptomatic, with no family history of the disease, they may present with significant pathology or as an emergency during pregnancy. Patients can undergo cardiac

surgery during pregnancy, but it is known to carry a high risk of mortality for both the mother and fetus.²

The literature on cardiac surgery during pregnancy is dominated by reports on patients who have undergone mitral valve repair or replacement, without specific attention to the details of cardiopulmonary bypass (CPB).³ A few reports have discussed surgery on the aortic valve and thoracic aorta during pregnancy.⁴ Therefore, data are limited regarding the outcomes of aortic surgery in pregnancy, as is knowledge about optimal perioperative management. We have previously presented our initial case series and conduct of CPB.⁴ The aim of the current paper is to describe our management of aortic surgery during pregnancy and present the results of our current series with specific attention to CPB and fetal monitoring.

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PATIENTS AND METHODS

Patients

All patients who underwent aortic and aortic valve surgery during pregnancy at St George's Hospital, from January 2004 until October 2013, were identified from a prospectively collected database. Patient demographics and operative details were recorded. All patients were followed up locally. Surgery was performed in the second trimester when possible. Patients presenting early in pregnancy were

Abbreviation and Acronym

CPB = cardiopulmonary bypass

managed conservatively until the second trimester, if possible, to allow completion of organogenesis. Completion to full-term pregnancy before surgery was prevented, to reduce the risk of rupture or heart failure during delivery. Permission was obtained for publication of this series.

Maternal and Fetal Monitoring

Maternal uteroplacental perfusion was monitored by measuring Doppler indices in both uterine arteries.⁵ Fetal monitoring consisted of serial assessments of Doppler indices in the umbilical and middle cerebral arteries using transabdominal Doppler ultrasound.⁶ The transvaginal route was utilized when the surgical field precluded the use of the transabdominal approach.

Surgical Technique

An opiate-based, balanced anesthetic technique, with propofol and muscle relaxation, is used for all patients. Cerebral oximetry monitoring is established pre-induction, and anesthetic doses are carefully titrated to maintain adequate invasive arterial pressure and cerebral oxygen saturation. Standard maternal monitoring for adult cardiac surgery was used in all patients. Patients were positioned supine in the lithotomy position to allow surgical access to the chest and concomitant transvaginal scanning. Because patients were in a relatively early stage of pregnancy, we did not use special measures to prevent aortocaval compression. All procedures were performed via median sternotomy.

Cardiopulmonary Bypass

CPB was established using central aortic and right atrial cannulation at 36°C, with pulsatile perfusion. CPB is established using a Stockert S5 modular heart-lung machine (Sorin Group, Milan, Italy). Pulse mode is enabled with initial pulse parameters set as follows: pulse frequency, 60/min; pulse width, 30%; and base flow, 30%. Standard CPB flow rate is 2.4 L/min/m² body surface area. The flow rate is increased by 20% in pregnant patients. Hemoglobin is maintained above 9 g/dL during the perioperative period. In the patient with aortic dissection, central aortic cannulation was achieved using periaortic ultrasound and transesophageal echocardiography. Strict avoidance of vasoconstrictors and blood products was maintained when possible, to avoid feto-placental vasoconstriction. CPB and cross-clamp times were kept to a minimum. Circulatory arrest was avoided in all cases.

Follow-up

All patients were reviewed at 6 weeks after discharge and, in addition, were seen as required by the obstetric team. Fetal assessment was repeated at 2 to 4 weeks postsurgery to assess uteroplacental function by Doppler ultrasound and exclude the development of fetal brain abnormalities as a consequence of prolonged intraoperative fetal hypoxemia.⁷

Statistics

Data are presented as median with interquartile range, unless stated otherwise.

RESULTS

During the study period, 11 patients underwent surgery during pregnancy. Median age was 28 years (range, 26-31 years) with a gestational age of 19 weeks (range, 16-21 weeks). Four patients had Marfan syndrome, and 2 had

undergone previous cardiac surgery. Patient characteristics and diagnosis are shown in Table 1. Six patients had aortic root dilatation with aortic regurgitation, and 5 had aortic stenosis. Those with stenosis presented in congestive cardiac failure. The operative procedures were aortic root replacement (tissue valve, n = 5; homograft, n = 1), aortic valve replacement (n = 3), valve-sparing root replacement (n = 1), and aortic and mitral valve replacements (n = 1), as shown in Table 1. Mean CPB and cross-clamp times were 105 and 89 minutes, respectively.

Figure 1 demonstrates typical fetal hemodynamics throughout the perioperative period, comparing maternal mean arterial pressure to fetal heart rate and the uterine artery pulsatility index. At induction of anesthesia (*point A*), despite maintenance of maternal mean arterial pressure and fetal heart rate, the pulsatility index fell. Once CPB was established (*point B*), the hemodynamics were maintained. The mother was weaned from bypass at *point C*. The importance of multimodality fetal monitoring is highlighted by episodes of reduced fetal perfusion, despite normal fetal heart rate. This reduction in perfusion would not be apparent if only fetal heart rate were measured.

There were no strokes, and no re sternotomy for bleeding. We aim to maintain an Hb of 9.0 g/dL, and 4 patients required transfusion of 2 units of red-cell concentrate. There were no maternal deaths, and all patients were discharged to their homes, well, at 7 days (range, 7-9 days); there were no intraoperative fetal deaths. However, 3 fetuses died within 1 week after surgery; all had features of hydrops. One of the deaths was concurrent with administration of β -blocker, associated with irreversible fetal bradycardia. Eight babies were born at term. At a mean follow-up of 4.2 years, all mothers and babies were well.

DISCUSSION

Our series includes only those patients who had no option to deliver their baby before surgery, owing to the urgency of the need for surgery and the low likelihood of survival of the fetus with premature delivery. The maternal mortality for cardiac surgery during pregnancy has been reported to be 2% to 14%.² Fetal mortality ranges from 15% to 30%.² A recent study by Elassy and colleagues⁸ reported 12 patients who required either aortic and/or mitral valve surgery during pregnancy. There were 10 intrauterine deaths in those undergoing surgery. Overall maternal mortality in the latter series was 8.7%. John and colleagues⁹ presented 21 patients undergoing cardiac surgery during pregnancy. Of these, 8 underwent aortic valve replacements, and 2 underwent aortic aneurysm repairs. Two fetal deaths occurred in this group, one during aortic valve replacement and the other during aneurysm repair. There were no maternal deaths.

TABLE 1. Demographics of patients undergoing aortic surgery during pregnancy using pulsatile, normothermic CPB

Maternal age (years)	Gestation at time of surgery (weeks)	Diagnosis	Type of surgery	Gestation at delivery (week of 40)	Fetal outcome
31	11	Aortic regurgitation, root 6.9 cm, Marfan	Aortic root replacement (porcine)	38	Well
38	15	Aortic stenosis + mitral stenosis	Aortic valve replacement + mitral valve replacement (porcine)	16	Died
24	16	Aortic stenosis, previous AVR	Redo homograft root replacement	38	Well
29	18	Aortic regurgitation, root 5.9 cm, Marfan	Aortic root replacement (bovine)	19	Died
26	19	Aortic stenosis, previous open valvotomy	Redo aortic valve replacement (porcine)	38	Well
24	19	Aortic stenosis	Aortic valve replacement (porcine)	38	Well
27	19	Aortic regurgitation, root 6.7 cm, Marfan	Aortic root replacement (bovine)	38	Well
31	20	Aortic stenosis	Aortic valve replacement (porcine)	21	Died
28	21	Aortic dissection, asc aorta 4.5 cm	Aortic root replacement (porcine)	38	Well
29	21	Aortic regurgitation, root 6.4 cm	Valve-preserving aortic root replacement	38	Well
28	24	Aortic regurgitation, root 7.2 cm, Marfan	Aortic root replacement (porcine)	37	Well

AVR, Aortic valve surgery; asc, ascending.

Pregnancy results in significant hemodynamic changes, to meet the increased metabolic needs of the mother and fetus. Cardiac output is increased by up to 50%, resulting from an increase in the circulating volume and heart rate.¹⁰ These changes are compensated for by a reduction in systemic vascular resistance. In addition, hypercoagulability occurs, owing to increased fibrinogen and platelet adhesiveness. In patients with underlying cardiac pathology, such as aortic stenosis, these alterations can result in acute cardiac failure that requires urgent valve replacement. In those with a predisposition to aortic aneurysm, the hemodynamic changes, in addition to hormonal alteration increasing the elasticity of the aortic wall, increase the chance of dilatation of the aorta or acute dissection.

The natural history of aortic aneurysms has been well documented. It is known that the larger the aortic diameter, the greater the growth rate and chance of rupture or dissection.¹¹ During the course of a normal pregnancy, the aortic diameter increases a small amount. This increase is significantly larger in the presence of hypertension, with

the maximal diameter occurring in the final few weeks of pregnancy.¹² In patients with Marfan Syndrome, the aorta was found to grow more rapidly during pregnancy, compared with the growth in an age-matched cohort.¹³ Furthermore, pregnancy increased the likelihood of adverse outcomes and longer-term need for aortic surgery.¹³ Therefore, the threshold for intervention on the ascending aorta in pregnancy must be lower, and such patients should not be allowed to go to full-term pregnancy, because of the increased risk of rupture.

The challenges of cardiac surgery during pregnancy vary with the stage of pregnancy. In the first trimester, there is a significant risk of congenital anomalies. In the third trimester, hemodynamic changes in the mother create significant risks of hemodynamic collapse to both the mother and fetus, while establishing and weaning from CPB. The second trimester is thought to be the safest time to carry out cardiac surgery, as the main organogenesis of the fetus has been completed but the large hemodynamic changes in the mother's circulation are not fully established.

CPB has multiple effects on the pregnant uterus, as a result of changes in pressure, flow, and temperature. Fetal death is most commonly noted during the cooling and rewarming phases of bypass, which can be avoided with near-normothermic bypass. Fetal outcomes in a series comprising both hypothermic and normothermic bypass have been shown to be significantly worse in the hypothermia group.¹⁴ Hypothermic circulatory arrest almost invariably results in fetal demise^{15,16} and therefore should be avoided; on the other hand, success has been reported in isolated cases.¹⁷

The normal uterine vasculature in early pregnancy requires high-pressure, pulsatile flow patterns to achieve good uteroplacental perfusion. Low-flow, nonpulsatile perfusion causes hypoxia in the uterus, initiating

FIGURE 1. Typical fetal hemodynamics throughout the perioperative period, comparing maternal mean arterial pressure (red line) with fetal heart rate (black line) and uterine artery pulsatility index (blue line). bpm, Beats per minute.

contractions. We therefore use pulsatile perfusion while maintaining high pressure and flow throughout. In an experimental model, placental blood flow was significantly increased with pulsatile perfusion.¹⁸ This increase was partly due to the release of nitric oxide, an arterial vasodilator, which has been shown to be at significantly higher levels during pulsatile perfusion.¹⁹ In addition, the same model showed significantly less activation of the renin-angiotensin system, which may contribute to higher placental blood flow. We avoid the routine use of vasoconstrictors unless they are absolutely necessary.

In addition to full invasive monitoring of the mother, in this series, we used continuous, serial, fetal monitoring via Doppler ultrasonography,¹⁰ which allows real-time assessment of blood flow in the umbilical and middle cerebral arteries. An increase in umbilical artery resistance, and a decrease in middle cerebral artery resistance, are typical of the changes seen with fetal hypoxemia.²⁰ These changes reflect the so-called brain-sparing effect of fetal arterial redistribution, which is seen as an attempt to maintain fetal brain oxygenation under hypoxic conditions. Such monitoring allows optimal control of CPB, to maintain adequate fetal oxygenation intraoperatively. If fetal distress occurs, it prompts us to review all parameters to ensure that they are optimal. Despite optimum parameters, signs of ongoing fetal distress may lead to further measures. In the case of fetal bradycardia, we may give atropine. However, the safety of the mother is always the priority.

In conclusion, aortic surgery during pregnancy carries a high risk to both mother and baby. With full maternal and fetal monitoring, and attention to cardiopulmonary bypass, pulsatile perfusion, near-normothermia, and avoidance of vasoconstrictors, risks may be minimized.

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