openheart

Main operating room deliveries for patients with high-risk cardiovascular disease

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To cite: Albright CM, Steiner J, Sienas L, *et al*. Main operating room deliveries for patients with high-risk cardiovascular disease. *Open Heart* 2023;**10**:e002213. doi:10.1136/openhrt-2022-002213

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Received 16 November 2022
Accepted 27 January 2023

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ABSTRACT

Background High-risk cardiovascular disease (CVD) prevalence in pregnant patients is increasing. Management of this complex population is not well studied, and little guidance is available regarding labour and delivery planning for optimal outcomes.

Objective We aimed to describe the process for and outcomes of our centre's experience with the main operating room (OR) caesarean deliveries for patients with high-risk CVD, including procedural and postpartum considerations.

Study design We performed a retrospective evaluation of pregnant patients with high-risk CVD who delivered in the main OR at a large academic centre between January 2010 and March 2021. Patients were classified by CVD type: adult congenital heart disease, cardiac arrest, connective tissue disease with aortopathy, ischaemic cardiomyopathy, non-ischaemic cardiomyopathy or valve disease. We examined demographic, anaesthetic and procedure-related variables and in-hospital maternal and fetal outcomes. Multidisciplinary delivery planning was evaluated before and after formalising a cardio-obstetrics programme.

Results Of 25 deliveries, connective tissue disease (n=9, 36%) was the most common CVD type, followed by non-ischaemic cardiomyopathy (n=5, 20%). Scheduled deliveries that went as initially planned occurred for six patients (24%). Fourteen (56%) were unscheduled and urgent or emergent. Patients in modified WHO Class IV frequently underwent unscheduled, urgent deliveries (64%). Most deliveries were safely achieved with neuraxial regional anaesthesia (80%) and haemodynamic monitoring via arterial lines (88%). Postdelivery intensive care unit stays were common (n=18, 72%), but none required mechanical circulatory support. There were no in-hospital maternal or perinatal deaths; 60-day readmission rate was 16%. Some delivery planning was achieved for most patients (n=21, 84%); more planning was evident after establishing a cardio-obstetrics programme. Outcomes did not differ significantly by CVD group or delivery era.

Conclusions Our experience suggests that short-term outcomes of pregnant patients with high-risk CVD undergoing main OR delivery are favourable. Multidisciplinary planning may support the success of these complex cases.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ High-risk cardiovascular disease (CVD) in pregnant patients is increasingly common. Delivery in a main operating room (OR), as opposed to labour and delivery units, may be necessary in certain cases where the anticipated need for acute, multidisciplinary assistance is high. There are no data regarding the types of high-risk CVD for which main OR caesarean delivery is best used, nor of the outcomes for deliveries performed in this location.

WHAT THIS STUDY ADDS

⇒ This study provides information about delivery timing, monitoring and outcomes for pregnant patients with high-risk CVD. Patients underwent caesarean deliveries in the main OR due to their cardiac risk, and most had favourable outcomes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study reports the clinical experience of a high-volume, complex cardio-obstetrics centre. Findings may provide practical guidance for the care of such patients, for example intrapartum monitoring. It may also spur ideas for future research, such as the impact of multidisciplinary cardio-obstetrics teams or the refinement of risk stratification models.

INTRODUCTION

The landscape of cardiovascular disease (CVD) among patients of childbearing age has evolved significantly over the past several decades. Increasing maternal age, higher incidence of cardiovascular risk factors such as hypertension and diabetes and improved survival into adulthood of patients with congenital heart disease have all been important contributors to the high burden of CVD encountered in pregnancy and to the fact that CVD has become the leading cause of maternal mortality in the USA.[1]

The normal physiologic changes of pregnancy, which include increases in cardiac output and heart rate, expansion of intravascular volume, hypercoagulability, and decrease in systemic vascular resistance, may

all confer an increased risk for cardiovascular events and mortality among patients with CVD or CVD risk factors. The physiological stress of labour and delivery (L&D) adds an additional, more acute component of strain on the cardiovascular system, particularly in the second stage of labour when the Valsalva manoeuvre is repeatedly performed.[2 3] Thus, it is recommended that deliveries for patients with high-risk CVD take place in a controlled environment, ideally at medical centres with an experienced cardio-obstetrics team. Cardio-obstetrics teams frequently consist of maternal–fetal medicine specialists, cardiologists and obstetric anaesthesiologists, with assistance as needed from intensivists, cardiothoracic (CT) surgeons and CT anaesthesiologists.[4] For most patients with CVD, contemporary approaches favour spontaneous or induced labour and vaginal delivery under titrated neuraxial analgesia and possible operative vaginal delivery to shorten the second stage. However, a caesarean delivery (CD) is still recommended for obstetric indications and when life-threatening maternal conditions, such as acute cardiovascular decompensation, warrant rapid delivery.[3 5 6]

In many instances, CD in patients with CVD can be safely performed in L&D units under the guidance of an experienced obstetric anaesthesiology team. However, in the setting of very high-risk disease, or in the face of haemodynamic instability requiring urgent cardiovascular support, delivery in the main operating room (OR) may be needed to provide the optimal setting for any urgent cardiac interventions. Decisions on the location, timing and overall management and flow of such deliveries are spearheaded by the cardio-obstetrics team and are done in close collaboration with the intensive care unit (ICU) and interventional cardiology teams. While data on mode of delivery and necessary hospital resources for these highest risk patients are emerging, to our knowledge there are currently no data regarding the preferred physical location for a CD. Similarly, to our knowledge, there are no data on the types of conditions for which main OR CD is best used. In this retrospective study, we describe the process for and outcomes of our centre's experience with the main OR deliveries for patients with high-risk CVD.

METHODS

We conducted a retrospective study of pregnant patients with high-risk CVD who underwent main OR CD. We queried our internal OR Scheduling database, SQL Server Reporting Services (Microsoft, Redmond, Washington, USA), to identify our sample, which included adults aged≥18 years who had a CD in the main OR (as opposed to the L&D operative suite) at the University of Washington, Montlake campus from January 2010 through March 2021. We then narrowed our sample by identifying, through manual chart review, patients with high-risk CVD as the primary indication for delivery in the main OR. We considered the following to be cardiac indications for CD: severe systemic ventricular dysfunction (left ventricular ejection fraction<30%), severe symptomatic outflow tract obstruction (valvular, subvalvular or supravalvular peak pressure gradient>40 mm Hg), severe systemic atrioventricular valve stenosis (valve area<1.5 cm^2), profound cyanosis (resting saturation<85%), high-risk aortopathy with aortic dilation or dissection, or incessant arrhythmia not responsive to therapy. Chart abstraction was performed manually by the authors to collect demographic and clinical data from the electronic health record (EHR), including cardiac and pregnancy event history, comorbidities, medications, key imaging data, delivery information, and postpartum events and disposition. Standard clinical definitions of conditions such as fetal growth restriction were used; the presence or absence of any condition was abstracted as documented by a clinician in the EHR.

Using pertinent elements of the clinical data, we assigned a New York Heart Association (NYHA) heart failure (HF) class, modified WHO (mWHO) class[7] and a Cardiac Disease in Pregnancy Study 2 (CARPREGII) Score[8] to each patient. This was done separately by a cardiologist and the primary abstractor (maternal fetal medicine specialist, anaesthesiologist or different cardiologist), and values were compared for validation. Each patient was also assigned a cardiac 'stoplight' colour symbolising their level of pregnancy risk. Patients classified as 'red' were mWHO class 3 or 4 or had a CARPREGII Score>4. Patients classified as 'yellow' were mWHO class II or II–III, had a CARPREGII Score 2–4 or were on full systemic anticoagulation (such as with heparin or warfarin). To be classified as 'green', none of the above could be present. In addition, patients were placed into mutually exclusive groups based on the predominant CVD type: adult congenital heart disease (ACHD), cardiac arrest, connective tissue disease with aortopathy or other significant vascular involvement, ischaemic cardiomyopathy, non-ischaemic cardiomyopathy or valve disease.

Clinical data and outcomes were descriptively assessed, using mean±SD or percentages, as appropriate. Timing of delivery was stratified based on urgency. Cases were either scheduled and went as planned, unscheduled and non-urgent (changed by ≥1 day), unscheduled and urgent (occurring same day), or unscheduled and emergent (requiring immediate delivery).

Elements of delivery planning that were assessed for this study included: (1) preanaesthesia consultation, which could have occurred either in clinic or on admission to the hospital prior to delivery; (2) a multidisciplinary care conference that included representatives from obstetrics, cardiology, anaesthesia, nursing and OR staff; and (3) an alert care plan, a summary document in the EHR containing pertinent delivery planning elements for all care providers to review prior to delivery or in case of urgent delivery. Elements of delivery planning were descriptively evaluated and stratified by delivery year: 2010–2017 vs 2018–2021, pre and post the formalisation of the combined

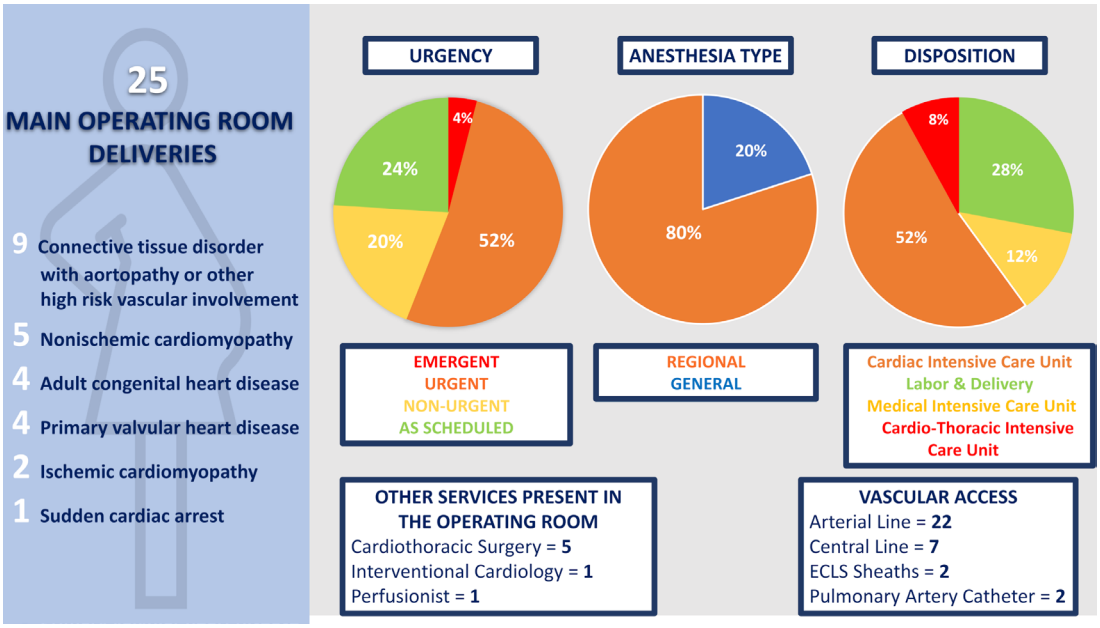

Figure 1 Characterisation of the study sample and primary findings. ECLS, extracorporeal life support.

cardio-obstetrics programme at our institution. Clinical outcomes such as delivery urgency, length-of-stay, post-OR disposition and readmission were evaluated by CVD group as well as year of delivery.

RESULTS

Between January 2010 and March 2021, 25 deliveries for 25 unique patients took place via CD in the main OR due to high-risk CVD (figure 1). These patients were predominantly white (n=15, 60%), with public insurance (n=14, 56%), and with a body mass index in the normal (18.5–24.9 kg/m^2) or overweight (≥25 kg/m^2 and <30 kg/m^2) categories (n=10 (40%) and n=7 (28%) for normal and overweight, respectively). Types of CVD in the patient population were: presence of a connective tissue disorder with an associated aortopathy or other high-risk vascular involvement in nine patients (36%), non-ischaemic cardiomyopathy in five (20%), valvular heart disease in four (16%) (one with underlying ACHD whose primary issue was mechanical aortic valve thrombosis), ACHD in four (16%), ischaemic cardiomyopathy in two (8%) and cardiac arrest with no prior medical history in one patient (4%). All patients had a cardiac 'stoplight' colour of red (92%) or yellow (8%). There was no difference between abstractors in the NYHA class, mWHO class and CARPREGII Score assignment. Detailed information for the study cohort, including individual patient data, is presented in table 1.

Delivery timing

The median gestational age at hospital admission for delivery was 33 weeks and 1 day (range 22 weeks and 4 days to 40 weeks 0 days), and five (20%) of the patients required an antepartum ICU admission, all for cardiac indications. The median time from admission to delivery was 5 days (range 0–70 days). Four patients (16%) had a failed trial of labour and three (12%) were undergoing repeat CD.

Scheduled CD that went as initially planned occurred for six patients (24%). However, 5 (20%) were unscheduled and non-urgent, 13 (52%) were unscheduled and urgent and 1 (the patient with cardiac arrest) was unscheduled and emergent. Of those who underwent unscheduled and urgent delivery, seven (54%) had an obstetric reason for CD, five of which occurred in the setting of non-reassuring fetal status. Delivery for six patients (24%) occurred in a hybrid OR due to potential need for interventional cardiology or cardiac surgery services. Overall, seven deliveries (28%) occurred on a weekend, six of which were unscheduled and urgent, while one was unscheduled and emergent. When divided by disease severity, 7 of the 11 patients (64%) who were classified as mWHO Class IV underwent unscheduled and urgent deliveries—predominantly as a result of either acute HF or symptomatic severe valve disease.

Anaesthesia and surgical procedures

Most patients (n=20, 80%) were delivered with neuraxial regional anaesthesia. Twenty-two patients (88%) had an arterial line, seven (28%) had a central line, two (8%) had a pulmonary artery catheter and two (8%) had extracorporeal life support sheaths placed in anticipation of possible need for urgent extracorporeal membrane oxygenation cannulation. Two patients had an implantable cardioverter-defibrillator (ICD); in one, a magnet was used in the OR and in the other the ICD was interrogated and reprogrammed prior to the case. Five patients were anticoagulated with heparin products. None were on warfarin, and none required anticoagulation reversal.

Table 1 Patientdescriptions

*	Patient description	Other high-risk features	Gestational age at delivery (weeks)	Year	CARPREG II Score	mWHO Score	NYHA class	Delivery urgency	Post-OR disposition	Additional procedure during hospitalisation
Adult congenital heart disease (N=4)										
	33 years old, G2P0100 Newly identified anomalous left coronary artery from the pulmonary artery, LVEF 30%	Systemic lupus erythematosus	35.3	2013	8	IV	III	U/U	MICU Support†	Cardiac catheterisation
	33 years old, G5P0131 Univentricular congenital heart defect with Fontan circulation, chronic cyanosis	Systemic lupus erythematosus Lupus nephritis Liver cirrhosis	25.4	2018	6	III	II	U/E	CCU	–
	36 years old, G1P0 Tricuspid atresia with Fontan circulation, on anticoagulation	Placental haematoma Supraventricular tachycardia	33.3	2019	6	III	I	U/U	CCU	–
	37 years old, G3P2002 Severe subvalvular pulmonic stenosis (160 mm Hg peak)	Monochorionic–diamniotic twins	36.4	2020	4	III	III	U/U	CCU	–
Cardiac arrest (N=1)										
	33 years old, G1P0 Out-of-hospital cardiac arrest (ventricular tachycardia)	–	30.0	2017	7	II–III	I	U/E	MICU	Cardiac catheterisation ICD placement
Connective tissue disorder (N=9)										
	31 years old, G1P0 Marfan syndrome with dilated aortic root (4.9 cm) and chronic type B aortic dissection	–	37.6	2011	5	III	II	AS	L&D	–
	20 years old G1P0 Ehlers-Danlos type 4 with peripheral vascular aneurysms	–	37.6	2012	3	II–III	I	AS	L&D	–
	27 years old, G1P0 Marfan syndrome with aortic root dilation (4.4 cm)	–	39.9	2012	3	III	I	U/N	L&D	–
	30 years old, G5P1212 Ehlers-Danlos type 4 with aortic root dilation (4.0 cm) and uterine rupture in previous pregnancy	Dichorionic diamniotic twins; Loss of variability on fetal monitoring	27.0	2013	3	III	I	U/U	L&D	Tunnelled catheter (IV access)

Continued

Table 1 Continued

*	Patient description	Other high-risk features	Gestational age at delivery (weeks)	Year	CARPREG II Score	mWHO Score	NYHA class	Delivery urgency	Post-OR disposition	Additional procedure during hospitalisation
	39 years old, G1P0 Marfan syndrome with multilevel aortic root dilation (elevated indexed diameter)	–	40.3	2014	3	II–III	I	U/N	L&D	–
	41 years old, G8P1334 Marfan syndrome, chronic type B aortic dissection	–	32.3	2016	6	IV	II	U/N	MICU Support†	–
	30 years old, G3P2002 Marfan syndrome with aortic root dilation (4.4 cm)	–	36.7	2019	3	III	I	AS	L&D	–
	27 years old, G1P0 Marfan syndrome with aortic root dilation (3.8 cm)	Type B aortic dissection during pregnancy	30.2	2020	7	IV	I	AS	CT ICU	–
	37 years old, G1P0 Marfan syndrome with aortic root replacement, severe mitral regurgitation from endocarditis	–	37.0	2020	5	III	II	U/U	CCU	Cardiac surgery
Ischaemic cardiomyopathy (N=2)										
	38 years old, G2P0010 Ischaemic cardiomyopathy, LVEF 35%–40%	Obstructing fibroids with suprapubic catheter	37.9	2015	7	III	II	AS	L&D	–
	38 years old, G3P0121 Multivessel coronary disease with bypass surgery; Ischaemic cardiomyopathy, LVEF 35%–40%	Graft occlusion (2) Obesity type 2 diabetes Hypertension	34.0	2020	7	III	II	AS	CCU	–
Non-ischaemic cardiomyopathy (N=5)										
	33 years old, G1P0 Dilated cardiomyopathy, LVEF 20%	Methamphetamine use	29.9	2013	4	IV	IV	U/U	CCU	–
	21 years old, G1P0 Dilated cardiomyopathy, LVEF 45%	Recurrent NSVT in third trimester	39.0	2014	6	II–III	I	U/U	CCU	–
	34 years old, G2P1001 Non-ischaemic cardiomyopathy, LVEF 25%	Heart failure exacerbation during pregnancy	38.3	2016	11	IV	IV	U/N	CCU	–
	42 years old, G4P1112 Non-ischaemic cardiomyopathy, LVEF 20%	Type 2 diabetes Hypertension Obesity Hypothyroidism Kidney disease	33.1	2017	5	IV	III	U/U	CCU	–

Continued

Table 1 Continued

*	Patient description	Other high-risk features	Gestational age at delivery (weeks)	Year	CARPREG II Score	mWHO Score	NYHA class	Delivery urgency	Post-OR disposition	Additional procedure during hospitalisation
	25 years old, G1P0 Dilated cardiomyopathy, LVEF 20%	Sepsis during pregnancy	36.3	2020	7	IV	IV	U/U	CCU Support†	–
Valve disease (N=4)										
	27 years old, G3P2002 Bioprosthetic mitral valve endocarditis with severe mitral valve regurgitation	Severe pulmonary hypertension Severe tricuspid regurgitation	30.2	2014	11	IV	III	U/U	CT ICU	Cardiac surgery
	19 years old, G1P0 Truncus arteriosus post Rastelli repair and with mechanical Bentall	Mechanical aortic valve thrombosis	34.1	2014	8	IV	III	U/N	CCU	Cardiac surgery
	33 years old, G4P1021 Severe mitral stenosis	Atrial fibrillation Fetal growth restriction	35.7	2020	7	IV	I	U/U	CCU	–
	29 years old, G2P1001 Symptomatic severe aortic stenosis	–	37.8	2021	3	IV	II	U/U	CCU	–

*'Stoplight' colour, indicating level of pregnancy risk: green (low; none present in this study), yellow (medium), red (high).
†Pharmacologic circulatory support with vasopressor, inotrope, or vasodilator therapy.
AS, as scheduled; CCU, cardiac intensive care unit; CT ICU, cardiothoracic intensive care unit; ICD, implantable cardioverter-defibrillator; L&D, labour and delivery unit; LVEF, left ventricular ejection fraction; MICU, medical intensive care unit; NSVT, non-sustained ventricular tachycardia; U/E, unscheduled, emergent; U/N, unscheduled, non-urgent; U/U, unscheduled, urgent.

Table 2 Outcomes by disease group

	ACHD	Arrest	CTD	ICM	NICM	Valve	
	N=4	N=1	N=9	N=2	N=5	N=4	P value
OR urgency, n (%)							<0.01
Scheduled	0	0	4 (44.5)	2 (100)	0	0	
Non-urgent	0	0	3 (33.3)	0	1 (20)	1 (25)	
Urgent	4 (100)	0	2 (22.2)	0	4 (80)	3 (75)	
Emergent	0	1 (100)	0	0	0	0	
OR Dispo, n (%)							0.03
L&D	0	0	6 (66.7)	1 (50)	0	0	
MICU	1 (25)	1 (100)	1 (11.1)	0	0	0	
CCU	5 (75)	0	1 (11.1)	1 (50)	5 (100)	3 (75)	
CT ICU	0	0	1 (11.1)	0	0	1 (25)	
Total LOS							0.69
Mean (SD)	23.8 (29.1)	6 (n/a)	28.4 (26.5)	17.5 (13.4)	18.8 (14.9)	10.3 (6.8)	
Median (range)	11.5 (5–67)	6 (n/a)	23 (5–77)	17.5 (8–27)	9 (6–36)	9 (4–19)	
Antepartum LOS							0.37
Mean (SD)	17.5 (25.8)	0 (n/a)	19.8 (23.0)	12.0 (14.1)	12.4 (13.4)	2.5 (3.3)	
Median (range)	6.5 (1–56)	0 (n/a)	15 (1–70)	12 (2–22)	5 (0–31)	1.5 (0–7)	
Postpartum LOS							0.90
Mean (SD)	6.3 (3.3)	6 (n/a)	8.7 (6.8)	5.5 (0.7)	6.4 (3.2)	7.8 (3.5)	
Median (range)	5 (4–11)	6 (n/a)	7 (4–26)	5.5 (5–6)	5 (4–12)	7.5 (4–12)	
Postpartum ICU LOS	(n=4)	(n=1)	(n=3)	(n=1)	(n=5)	(n=4)	0.84
Mean (SD)	2.3 (1.3)	2 (n/a)	3 (2)	1 (n/a)	2.2 (1.8)	2 (0)	
Median (range)	2 (1–4)	2 (n/a)	3 (1–5)	1 (n/a)	2 (0–5)	2 (2)	
Readmission, n (%)	1 (25)	0	1 (11.1)	1 (50)	1 (25)	0	0.68

ACHD, adult congenital heart disease; CCU, cardiac care unit; CTD, connective tissue disease; CT ICU, cardiothoracic intensive care unit; Dispo, disposition; ICM, ischaemic cardiomyopathy; ICU, intensive care unit; L&D, labour and delivery; LOS, length of stay; MICU, medical intensive care unit; NICM, non-ischaemic cardiomyopathy; OR, operating room.

These deliveries were performed with general anaesthesia if it was not possible to wait until neuraxial anaesthesia could be safely used.

No major adverse outcomes occurred in any of the main OR deliveries. The median overall time in the OR was 156 min (range 66–225 min). This included in-room to case start time (median 61 min, range 11–110 min), procedure time (median 70 min, range 34–128 min) and case-end to out-of-room time (median 12 min, range 2–36 min). Two patients (8%) underwent transoesophageal echocardiography to guide intraoperative and postoperative fluid, inotrope and vasopressor administration. Median estimated blood loss was 700 mL (range 500–2577 mL).

Postdelivery care and maternal and fetal outcomes

Most patients were transferred to an ICU post delivery (n=18, 72%), either to a cardiac ICU (n=13, 52%), medical ICU (n=3, 12%) or CT surgery ICU (n=2, 8%). All patients with ACHD, cardiac arrest, non-ischaemic cardiomyopathy and valve disease had postdelivery ICU stays (table 2). Three patients (12%) required vasopressors, inotropes or vasodilators postoperatively, and none required mechanical circulatory support. The median length of postpartum ICU stay was 2 days (range 0–5 days). The seven patients (28%) who did not require ICU stays were transferred directly to L&D from the OR and treated with floor-level management. The median hospital stay following delivery was 6 days (range 4–26 days). Overall length of stay (antepartum and postpartum) was similar across disease groups (table 2). No in-hospital maternal deaths occurred. Four patients (16%) were readmitted within 60 days: two for obstetric reasons (one with a partial hysterotomy dehiscence, one for a wound infection) and two for cardiac reasons (one required urgent surgery for double chamber right ventricle with severe outflow tract obstruction, one underwent percutaneous coronary intervention).

There were 2 sets of twins born in the cohort, for a total of 27 neonates, with overall favourable outcomes. Four (15%) were diagnosed with antenatal fetal growth restriction. Median birth weight at delivery was 2288 g (range 548–4183 g) and the median 5 min Apgar score

was 9 (range 5–9). Overall, 18 (67%) were admitted to the neonatal intensive care unit (NICU), all related to prematurity. No perinatal mortality occurred.

One or more elements of delivery planning were achieved for the majority of patients (n=21, 84%). Significantly higher rates of planning, specifically of multidisciplinary care conferences and alert care plan documentation, were recorded after the formalisation of the cardio-obstetrics programme (table 3). The distribution of disease and risk scores as well as maternal and fetal outcomes remained unchanged by year of delivery.

DISCUSSION

Pregnant patients with high-risk CVD require frequent assessment throughout pregnancy, as well as detailed multidisciplinary planning for their L&D, with readiness to address urgent clinical events. In this study, we describe our centre's experience with the management of 25 patients with high-risk CVD who underwent CD in the main OR. Although maternal and fetal outcomes were generally favourable, only 24% of deliveries took place as originally planned, with over half (64%) of the patients in mWHO class IV undergoing an unscheduled and urgent delivery. Rising maternal morbidity and mortality in the USA calls for a delineation of the care components needed to successfully address various maternal and fetal needs, including facility capabilities and provider expertise.[9 10] The value of a dedicated cardio-obstetrics team to ensure specialised care for high-risk patients has been increasingly reported.[11 12] Our study suggests that access to a main OR for the highest risk cases may be an additional important factor for safe delivery.

Not every patient with high-risk CVD who requires CD must have it performed in the main OR. However, when significant peripartum complications are anticipated, the main advantage of a main OR delivery (over L&D) is the ability to quickly use mechanical circulatory support, perform emergent transcatheter procedures or achieve rapid sternotomy. While there is homogeneity of basic equipment found on L&D units, they may not have the physical infrastructure to support or space to use specialised equipment such as extracorporeal membranous oxygenation circuits, or have hybrid OR capabilities.[13] In our study, although this was not a direct comparison between main OR and L&D use, the most common type of CVD for which there was main OR delivery was connective tissue disease with aortopathy, given the potential for acute aortic complications. In such situations, the main OR may be the optimal location for multidisciplinary assistance from surgeons, perfusionists and interventional cardiologists.[4] Main OR use for potential need for increased resources is similarly reported in the obstetric literature on risk stratification and delivery location for abnormal placentation, with more complex cases preferentially delivered in a main OR.[14] In situations where the main OR is physically separated from L&D or the NICU, close collaboration with neonatology providers is

Table 3 Patientcharacteristics and outcomes by year

	2010–2017 N=15	2018–2021 N=10	P value
Patient characteristics			
Disease group, n (%)			0.56
ACHD	1 (6.7)	3 (30)	
Arrest	1 (6.7)	0	
CTD	6 (40.0)	3 (30)	
ICM	1 (6.7)	1 (10)	
NICM	4 (26.7)	1 (10)	
Valve	2 (13.3)	2 (20)	
mWHO class, n (%)			0.11
II–III	4 (26.7)	0	
III	4 (26.7)	6 (60.0)	
IV	7 (46.6)	4 (40.0)	
CARPREG II Score, median (range)	6 (3–11)	6 (3–7)	0.80
Individual planning elements			
Pre-anaesthesia consultation, n (%)	11 (73.3)	9 (90.0)	0.31
Multidisciplinary care conference, n (%)	5 (33.3)	8 (80.0)	0.02
Alert care plan, n (%)	7 (46.7)	9 (90.0)	0.03
Combination of planning elements			
None, n (%)	3 (20.0)	4 (16.0)	0.01
Any but not all, n (%)	9 (60.0)	10 (40.0)	
All, n (%)	3 (20.0)	11 (44.0)	
Outcomes			
Urgency of delivery, n (%)			0.15
Scheduled	3 (20)	3 (30)	
Non-urgent	5 (33.3)	0	
Urgent	6 (40)	7 (70)	
Emergent	1 (6.7)	0	
OR disposition, n (%)			0.09
L&D	6 (40)	1 (10)	
MICU	3 (20)	0	
CCU	5 (33.3)	8 (80)	
CTICU	1 (6.7)	1 (10)	
Total LOS			0.06
Mean (SD)	27 (24.8)	12.2 (8.9)	
Median (range)	12 (6–77)	7.5 (4–27)	
Antepartum LOS			0.13
Mean (SD)	18.4 (22.2)	6.8 (8.1)	
Median (range)	5 (0–70)	3 (0–22)	
Postpartum LOS (days)			0.07
Mean (SD)	8.6 (5.6)	5.4 (1.4)	
Median (range)	7 (4–26)	5.5 (4–8)	
Postpartum ICU LOS (days)			0.76

Continued

Table 3 Continued

	2010–2017 N=15	2018–2021 N=10	P value
Mean (SD)	2.1 (1.1)	2.3 (1.6)	
Median (range)	2 (0–4)	2 (1–5)	
Readmission, n (%)	2 (13.3)	2 (20.0)	0.66

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ACHD, adult congenital heart disease; CCU, cardiac care unit; CTD, connective tissue disease; CTICU, cardiothoracic intensive care unit; Dispo, disposition; ICM, ischaemic cardiomyopathy; ICU, intensive care unit; L&D, labour and delivery; LOS, length of stay; MICU, medical intensive care unit; NICM, non-ischaemic cardiomyopathy; OR, operating room.

imperative, to ensure that appropriate equipment and personnel are available for neonatal support. Important In addition to delivery location, type of anaesthesia must be carefully considered in high-risk patients with CVD. Neuraxial anaesthesia for CD is generally preferred to general anaesthesia, even in patients with known CVD. These patients can tolerate reduced intrathecal doses or carefully titrated epidural boluses.[15 16] However, concerns exist regarding its use in some patients, such as those on anticoagulation.[17] In our study, we did not identify complications related to the use of regional neuraxial anaesthesia, supporting safe use if appropriate transition strategies are employed. How to best monitor intraoperative haemodynamics is also a pertinent concern. Similar to existing literature,[16] we found that the use of arterial access to provide beat-to-beat monitoring remains the most common type of invasive monitor. Central venous and pulmonary artery catheters tended to be reserved for patients with acute cardiopulmonary decompensation and are likely not routinely needed, even in the presence of complex cardiac anatomy or physiology.[16 18] Through use of appropriate monitoring, supported by close clinical collaboration, high-risk CVD patients can remain safe during complex deliveries.

Despite the dynamic nature of these high-risk deliveries, the literature suggests that multidisciplinary delivery planning can help anticipate and plan for adverse events.[11 19–21] In our practice, this type of planning has improved team performance related to fluid communication between services and has also improved clinicians' confidence in managing complex cases. It is likely because of insufficient power that we did not see differences in outcomes as related to planning in this study. We do, however, note more frequent main OR deliveries following cardio-obstetrics programme formalisation. An explanation for this is that structured, more comprehensive planning may lead to increased monitoring and perhaps expanded criteria for main OR delivery. It is recognised that the utilisation of protocolised care and checklists ensures the best care for patients with postpartum haemorrhage.[22] Similar practices are likely to produce comparably favourable outcomes for patients with high-risk CVD, although future efforts should evaluate the ideal structure and organisation of cardio-obstetrics teams.

Our institution is a large ACHD and high-risk obstetrics referral centre with a long history of collaboration. To the authors' knowledge, this is the first study that has examined physical delivery location for the most complex cardio-obstetrics patients undergoing CD. Although this study is not intended to provide recommendations, it does provide valuable information for clinicians facing similarly complex patients in the absence of existing comprehensive data on this topic. However, certain limitations of this study should be considered. Primarily, that this is a retrospective evaluation at a single institution without a control group. There are no patients of equivalent CVD risk at our institution who do not deliver in the main OR, therefore direct comparison with a control group is not possible. Similarly, patients cannot be matched on mWHO class and CARPREG II Score since these inadequately classify overall risk. The development of future risk stratification models should include peripartum considerations. Second, this experience may not be entirely generalizable. Study participants were mainly white and publicly insured; we acknowledge the contribution of racism and issues surrounding socioeconomic status to increased CVD risk and maternal and fetal morbidity and mortality. Access to quality cardio-obstetric care is likely impacted by these characteristics, and while we assume that the decision for an established patient to deliver in the main OR is not, the possibility for implicit bias exists. Finally, details of decisions surrounding delivery timing and location may be subjective; however, these were systematically guided by standardised risk assessment tools and abundant clinical experience. Future studies would ideally examine larger, prospective, multicentre data.

In conclusion, delivery in the main OR may be reasonable for pregnant patients with high-risk CVD when the potential need for invasive and specialised cardiac therapies extends beyond the capabilities of the L&D unit. Favourable outcomes are possible, even for urgent deliveries, likely aided by the use of standardised risk assessment. Multidisciplinary team decision-making may assist in the success of these complex cases. Advances in treatment for both congenital and acquired CVD have been a major success of modern medicine, and with careful cardio-obstetric collaboration, we can continue to successfully support patients with CVD throughout their lives.

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Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the institutional review board of the University of Washington (STUDY00011786, 12 November 2020).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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