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Stratified Management of Cardiac Surgery for Structural Heart Disease during Pregnancy

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Keywords:

Structural heart disease; Stratified management; Cardiac surgery; Pregnancy; Outcome

Abbreviations:

CPB: Cardiopulmonary bypass; SHD: Structural heart disease; CHD: Congenital heart disease; PS: Pulmonary hypertension; SPS: Severe pulmonary stenosis; SMI: Severe mitral insufficiency; SAI: Severe aortic insufficiency; PMI: Prosthetic mitral insufficiency; PH: Pulmonary hypertension; SPH: Severe pulmonary hypertension; MVR: Mitral valve replacement; TVP: Tricuspid valve plasty; ICU: Intensive Care Union; ICP: Intrahepatic cholestasis of pregnancy; CO: Cardiac output; BP: Blood pressure; MHV: Mechanical heart valve; MMVD: Mechanical mitral valve dysfunction; PVP: Prosthetic valve perforation; W: Week; G: Gram; MDT: Multidisciplinary team; VHD: Valvular heart disease; ASD: Atrial septal defect; TI: Tricuspid insufficiency; STI: Severe tricuspid insufficiency; MS: Mitral stenosis; SMS: Severe mitral stenosis; DVT: Deep Venous Thrombosis; PTE: Pulmonary thromboembolism; NYHA: New York Heart Association; BVR: Bivalve replacement (mitral+aortic valve replacement); ASDR: Atrial septal defect repair; LVEF: Left ventricular ejection fraction; WHO: World Health Organization; AF: Atrial fibrillation; IE: Infective endocarditis; FGR: Fetal growth restriction; FHR: Fetal heart rate; D: Day; Y: Year

1. Abstract

1.1. Objective: We study pregnancy outcomes of cardiac surgery under cardiopulmonary bypass (CPB) at different stages and discuss stratified management of cardiac surgery under CPB in pregnant women with structural heart disease (SHD) from pre-pregnancy counseling through postpartum management.

1.2. Methods: We analyzed data from twelve pregnant women hospitalized with cardiac surgery at different stages with data collection from May 1, 2019 to May 1, 2022 in our hospital. This study retrospectively analyzes the outcomes of mother and fetus underwent cardiac surgery at different stages, focusing on stratified management of patients with cardiac surgery intervention, from pre-pregnancy counseling to delivery.

1.3. Results: Of the 15,217 pregnant women hospitalized during the study period, 71 (0.5%) had SHD, and twelve (16.9%) of them underwent CPB open-heart surgery. All twelve pregnant women were alive after CPB open-heart operation without other complications. Of these twelve cases, six fetuses survived, one was lost to follow-up, while five (41.7%) died, four of which died before cardiac intervention.

1.4. Conclusion: As the incidence of SHD during pregnancy increases, we must consider a multidisciplinary approach to optimal decision-making for the best outcomes for mothers and fetuses. It also requires that clinical cardiologists, especially staff on the ground, be familiar with the initial management of pregnant women with SHD.

2. Introduction

The incidence of cardiac disease during pregnancy is about 1–4% [1]. Cardiac disease complicates 2-4% of pregnancies and accounts for up to 15% of maternal mortality [1-2]. Maternal mortality is one of the main indicators of national health and socioeconomic development around the world. ROPAC (Registry of Pregnancy and Cardiac Disease) is an international prospective registry, which to study pregnant women with SHD. According to data from ROPAC, van Hagen et al mentioned that the total mortality in those women with severe mitral stenosis (MS) was 1.9% and that 50% developed heart failure during pregnancy [3-4]. Therefore, how to reduce the maternal mortality and optimize outcomes for mother and fetus has been one of the hot topics in the world.

Cardiac surgery under CPB during pregnancy is a very challenging decision, which is rare and is often more common in developing countries. A Swedish study suggested that only 40 women of 720,000 pregnant women (0.006%) registered in hospitals underwent cardiac interventions during pregnancy [5]. In the past, cardiac surgery under CPB during pregnancy is associated with higher maternal and fetal mortality.

Cardiac interventions or specialist follow-up before pregnancy is preferred for women with SHD. However, if the pregnancy is unplanned or if heart disease is not discovered until after the pregnancy, heart surgery may be a better option when pregnant women had severe symptoms. In general, cardiac surgery under CPB is not recommended during the perinatal period. Chandni Patel et al suggested that cardiac surgery under CPB is considered only when the medical treatment has failed and maternal condition is severe [6].

The second trimester is considered the best time for surgery because it is probably the safest time for both mother and fetus. If cardiac surgery is necessary during pregnancy, every effort should be made to reduce the risk to both mother and fetus. For instance, a multidisciplinary team (MDT), including Cardiac surgery, Cardiology, Anesthesiology, Obstetrics, Neonatology, Intensive Care Union (ICU), the timing of intervention, the grasp of surgical indication, the management of preoperative period, etc. Of course, postoperative management and follow-up should not be ignored. These are also recommended in the ESC (the European Society of Cardiology) Guide.

3. Methods

The study was based on the data of twelve pregnant women with structural heart disease who were hospitalized in the Obstetric Intensive Care Center of the Third Affiliated Hospital of Guangzhou Medical University, Guangdong, China from May 1, 2019 to May 1, 2022. SHD covered in this review included valvular heart disease (VHD), congenital heart disease (CHD), prosthetic valve dysfunction, and aortic aneurysm. Data collected included age, gestational age, hospitalization time, cardiac diagnosis, maternal medical history, other comorbidity, heart functional class, operation time and type, the nature of the surgery (elective or emergency), mode of delivery, maternal and fetal outcome as well.

The cardiac diagnosis all were confirmed by echocardiography before surgery. New York Heart Association (NYHA) classification was used to heart functional class. The time of cardiac surgery intervention was divided into three stages, including during pregnancy, postpartum within six weeks and more than six weeks. Stratified management, according to pre-pregnancy, pregnancy and postpartum.

Continuous variable data are expressed in terms of mean ± standard deviation, while categorical variables are expressed as frequency and percentage. We compared pregnancy outcomes of women with undergoing heart operation intervention at different stages of the perinatal period.

4. Results

Patients ranged in age from 24 to 39 years, with an average age of 30.9 ± 4.5 years. The hospitalization time ranged from 14 to 45 days, with an average time of 26.9 ± 15.6 days. The average gestational age of these women at the time of heart operation was 25.6 ± 6.9 weeks, with a gestational age range between 11 and 35 weeks. All were single pregnancies. By NHYA classification, three patients were classified as NHYA Grade II, five as NHYA Grade III, and four as NHYA Grade IV. The detailed baseline characteristics of the study women is presented in Table 1.

Of the 15,217 pregnant women hospitalized during the study period, 71 (0.5%) had SHD, and twelve (16.9%) of them underwent CPB open-heart surgery. Among these twelve surgical patients, there were seven (58.3%) cases of VHD, two (16.7%) cases of prosthetic valve dysfunction, two (16.7%) cases of CHD and one (8.3%) of aortic aneurysm. Prosthetic valve types include biological valves (n=2/10, 20%) and mechanical valves (n=8/10, 80%). In our cohort, VHD is basically mitral valve disease. There were eight (58.3%) cases of mitral valve replacement (MVR) and tricuspid valvuloplasty (TVP), two (16.7%) cases of atrial septal defect repair (ASDR), one (8.3%) of bivalve replacement (mitral+aortic valve replacement) (BVR), and one (8.3%) of Bentall surgery. The composition and proportion distribution of these patients by types of SHD, types of cardiac surgery, and types of prosthetic valves are summarized in Figure 1-3.

Five patients had cardiac surgery under CPB during pregnancy (three patients continued pregnancy after surgery, two patients performed cesarean section and cardiac surgery simultaneously), three patients had surgery within six weeks postpartum, and another four patients underwent surgery after six weeks postpartum. Nine (75%) of these twelve surgical patients had other comorbidities and seven (58.3%) had emergency cardiac surgery. Table 2 offer details on types of SHD, cardiac surgery procedures and time, nature of surgery, other comorbidity and prosthetic valve types of each patient.

All twelve pregnant women were alive after CPB open-heart operation without other complications, and two of them continued pregnancies to term and delivered fetuses successfully. Six fetuses survived, one was lost to follow-up, while five (41.7%) died (one with intracranial hematoma and intrauterine death at 32 weeks gestation, and four with abortion in early gestation), four of which died before cardiac intervention. Mode of delivery, time of delivery, maternal outcomes and fetal outcomes (birth weight, Apgar score) are shown in Table 3.

Table 1 Baseline characteristics of the patients

No	Age (y)	Weeks of gestation during surgery (w)	Time of hospitalization (d)	maternal medical history	NHYA classification
1	34	27	45	-	IV
2	24	23	31	-	III
3	29	25	24	Rheumatic heart disease was found in 2013	III
4	29	33	15	A family history of aortic aneurysms	II
5	28	35	45	-	III
6	31	30	24	MVR (mechanical valve) was performed for rheumatic heart disease in 2010	IV
7	24	21	42	-	IV
8	39	30	21	MVR (biological valve) was performed previously, but the operation time was unknown	III
9	32	16	17	CHD was diagnosed for more than 30 years	II
10	35	11	14	CHD was found in 2012	II
11	37	33	25	Rheumatic heart disease was found during pregnancy in 2019	III
12	29	23	20	-	IV

y, Year; w, Week; d, Day; MVR, Mitral valve replacement; CHD, Congenital heart disease

Table 2 Patients' type of cardiac disease and surgical information

No	Type of cardiac disease	Other comorbidities	Cardiac surgical procedure	Time of operation	Nature of surgery	Type of prosthetic valve
1	IE, SMI, STI	Gestational diabetes mellitus, chronic hepatitis	MVR+TVP	4/2/2020	Emergency	Mechanical valve
2	IE, SMI, TI	Hypokalemia	MVR+TVP	6/23/2020	Emergency	Mechanical valve
3	SMS, TI, SPH	Thalassemia	MVR	1/25/2022	Emergency	Mechanical valve
4	Aneurysm of ascending aorta, SAI	-	Cesarean section+Bentall	5/17/2020	Elective	Mechanical valve
5	IE, SMI	ICP	Cesarean section+MVR	1/29/2021	Emergency	Mechanical valve
6	PMI, MMVD, STI, PH	Schizophrenia	Second MVR+TVP, temporary cardiac surface pacemaker placement	6/12/2019	Emergency	Mechanical valve
7	IE, SMI (mitral valve perforation), SPH	Thrombo-cytopenia, renal insufficiency	MVR	9/4/2019	Emergency	biological valve
8	PVP with perivalvular leakage, SMI, STI, PH	Gestational diabetes mellitus, arrhythmia (AF)	Second MVR+TVP, pericardium dissection	6/16/2020	Emergency	Mechanical valve
9	ASD, TI, SPS	-	ASDR+TVP, dilatation of PS	1/6/2020	Elective	-
10	ASD, STI, SPS	-	ASDR+TVP	11/25/2019	Elective	-
11	SMI, SAI, STI, PH	Arrhythmia (AF), PTE, DVT	BVR+TVP	9/12/2019	Elective	Mechanical valve
12	SMS, STI, PH	Arrhythmia (AF), cerebral infarction	MVR+TVP, Radio frequency ablation of AF	5/7/2020	Elective	biological valve

IE, Infective endocarditis; SMI, Severe mitral insufficiency; STI, Severe tricuspid insufficiency; MVR, Mitral valve replacement; TVP, Tricuspid valvuloplasty; TI, Tricuspid insufficiency; SMS, Severe mitral stenosis; SPH, Severe pulmonary hypertension; SAI, Severe aortic insufficiency; ICP, Intrahepatic cholestasis of pregnancy; PMI, Prosthetic mitral insufficiency; MMVD, Mechanical mitral valve dysfunction; PH, Pulmonary hypertension; PVP, Prosthetic valve perforation; AF, Atrial fibrillation; ASD, Atrial septal defect; SPS, Severe pulmonary stenosis; ASDR, Atrial septal defect repair; PS, Pulmonary stenosis; PTE, Pulmonary thromboembolism; DVT, Deep Venous Thrombosis; BVR, Bivalve replacement

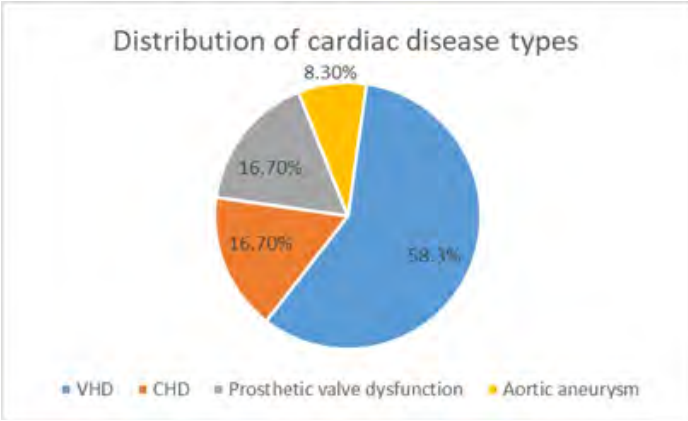

Figure 1: Distribution of cardiac disease types

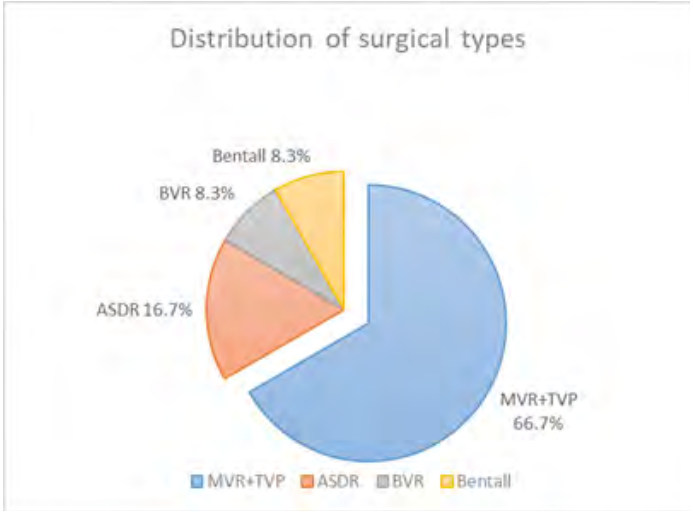

Figure 2: Distribution of surgical types

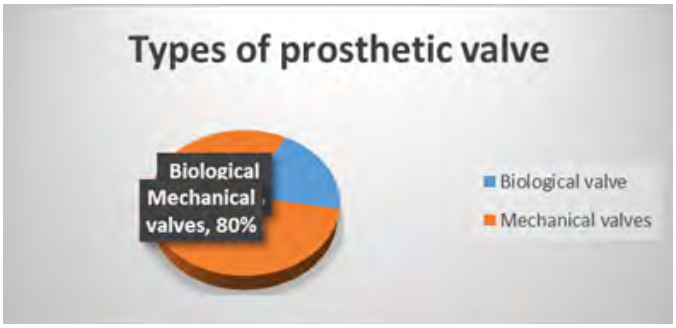

Figure 3: Types of prosthetic valve

Table 3: Mode of delivery, maternal and fetal outcomes

No	Mode of delivery	Time of delivery	Maternal outcomes	Fetal outcomes	Birth weight (g)	Five-minute Apgar score
1	Natural labor	6/5/2020	Survived without other complications	Small for gestational age infant	2370	10
2	Cesarean section	10/15/2020	Survived without other complications	Small for gestational age infant	2350	10
3	Odinopoeia	3/10/2022	Survived without other complications	Stillbirth (fetal intracranial hemorrhage)	1910	0
4	Cesarean section	5/17/2020	Survived without other complications	Preterm birth, low-birth-weight infant	1860	7
5	Cesarean section	1/29/2020	Survived without other complications	Preterm birth, low-birth-weight infant	2020	7
6	- (lost to follow-up)	-	-	-	-	-
7	Spontaneous abortion	8/24/2019	Survived without other complications	Stillbirth	-	-
8	Cesarean section	6/10/2020	Survived without other complications	Preterm birth, very low-birth-weight infant	1300	6
9	Odinopoeia	10/16/2019	Survived without other complications	Stillbirth	-	-
10	Abortion (forcep curettage)	9/27/2019	Survived without other complications	Stillbirth	-	-
11	Cesarean section	7/17/2019	Survived without other complications	Preterm birth, low-birth-weight infant	2200	8
12	Abdominal hysterotomy	3/19/2020	Survived without other complications	Stillbirth	-	-

g, Gram

5. Discussion

5.1. Pre-Conception Management and Risk Assessment

SHD has a significant impact on both mother and fetus from the beginning of pregnancy through the postpartum period. Cardiac disease always is the leading cause of non-obstetric maternal death [2]. Because of the hemodynamics adaptation changes in a pregnant woman, we may ignore her cardiac disease unless she shows severe symptoms. These adaptive changes include increases blood volume and cardiac output (CO), increases heart rate, and reductions blood pressure (BP), as mentioned in the ESC Guide [7]. This makes it difficult to diagnose and treat heart disease during pregnancy, and some patients may even need emergency surgery, which also increase maternal mortality rates associated with heart disease. It suggested that emergency cardiac surgery was associated with worse maternal outcomes and higher mortality in the study by Renato T et al, and fetal mortality rate may even reach 43.4% in Saeed M. R. Elassy et als' study [8-9]. In addition, pregnancy hypercoagulable state and anticoagulant problems increase the incidence of prosthetic valve thrombosis during pregnancy, which is an additional risk factor in patients with prosthetic valves implanted.

Pre-pregnancy counseling and management of pregnant women with SHD are of great importance. The counseling should be conducted by cardiologists and prenatal medicine specialists [7]. Moreover, it should status and risk assessment to determine suitability for pregnancy. Especially in patients with prosthetic heart valves, we need to evaluate more carefully, in addition to the above mentioned, including the assessment of function of prosthetic valves and anticoagulant issues. Echocardiography and electrocardiogram are most commonly used to evaluate cardiac aspects during pregnancy.

If possible, all women of childbearing age with SHD should have pre-pregnancy counseling and pregnancy management. Early identification and intervention (medication or surgery), should be performed to optimize maternal haemodynamics during pregnancy. Pregnant women with severe heart disease should have a cardiac surgery intervention before pregnancy [10]. As for those with SHD, we will relax indications for cardiac surgery. Surgical intervention before pregnancy was found to be a protective factor. Qin Fu et al retrospectively analyzed 173 women with a history of cardiac surgery before pregnancy in their study, and they found that only five (2.9%) of them had cardiac events, while 82 (20.9%) of 393 women who did not perform surgical intervention experienced a cardiac event [11].

All patients with complex cardiac disease during pregnancy should conduct a pregnancy risk assessment. In the current era, the commonly used assessment systems in domestic and overseas include CARPREG, ZAHARA system and the modified World Health Organization (WHO) risk classification. The modified WHO risk classification may be more appropriate to use clinically, as recommended by the ESC Guide [7]. This risk classification involves all known maternal cardiovascular risk factors, including the underlying heart disease and other comorbidity. It also includes contraindications for pregnancy that are not contained in the CARPREG and ZAHARA risk scores/predictors. The general principles of the modified WHO risk classification are listed in Table 4. And a practical application is given in Table 5 [7]. Pregnant women who are newly diagnosed with WHO III or above risk or whose conditions are more complex and cannot be clearly diagnosed and judged for risk classification should accept an MDT consultation timely for further diagnosis and evaluation in a tertiary or above hospital. In this study, all patients were evaluated to be in WHO III or IV. By the time transferred to our hospital, they had developed severe symptoms and some carried out emergency surgery.

To conclude, pre-conception management requires close monitoring by an MDT. Risk assessment for mothers should be individualized. Through early identification and timely intervention to optimize the mother's cardiovascular status to cope with the later pregnancy.

Table 4: The general principles of the modified WHO risk classification

Risk class	Risk of pregnancy by medical condition
I	No detectable increased risk of maternal mortality and no/mild increase in morbidity
II	Small increased risk of maternal mortality or moderate increase in morbidity
III	Significantly increased risk of maternal mortality or severe morbidity. Expert counselling required. If pregnancy is decided upon, intensive specialist cardiac and obstetric monitoring is needed throughout pregnancy, childbirth and the puerperium
IV	Extremely high risk of maternal mortality or severe morbidity; pregnancy contraindicated. If pregnancy occurs, termination should be discussed. If pregnancy continues, care as for class III

WHO, World Health Organization

Table 5: Modified WHO risk stratification: application

Conditions in which pregnancy risk is WHO I
• Uncomplicated, small or mild
- pulmonary stenosis
- patent ductus arteriosus
- mitral valve prolapse
•Successfully repaired simple lesions (atrial or ventricular septal defect, patent ductus arteriosus, anomalous pulmonary venous drainage).
• Atrial or ventricular ectopic beats, isolated
Conditions in which pregnancy risk is WHO II or III
WHO II (if otherwise well and uncomplicated)
• Unoperated atrial or ventricular septal defect
• Repaired tetralogy of Fallot
• Most arrhythmias
WHO II–III (depending on individual)
• Mild left ventricular impairment
• Hypertrophic cardiomyopathy
• Native or tissue valvular heart disease not considered WHO I or IV
• Marfan syndrome without aortic dilatation
• Aorta <45 mm in aortic disease associated with bicuspid aortic valve
• Repaired coarctation
WHO III
• Mechanical valve
• Systemic right ventricle
• Fontan circulation
• Cyanotic heart disease (unrepaired)
• Other complex congenital heart disease
• Aortic dilatation 40–45 mm in Marfan syndrome
• Aortic dilatation 45–50 mm in aortic disease associated with bicuspid aortic valve
Conditions in which pregnancy risk is WHO IV (pregnancy contraindicated)
• Pulmonary arterial hypertension of any cause
• Severe systemic ventricular dysfunction (LVEF <30%, NYHA III–IV)
• Previous peripartum cardiomyopathy with any residual impairment of left ventricular function
• Severe mitral stenosis, severe symptomatic aortic stenosis
• Marfan syndrome with aorta dilated >45 mm
• Aortic dilatation >50 mm in aortic disease associated with bicuspid aortic valve
• Native severe coarctation

LVEF, Left ventricular ejection fraction; NYHA, New York Heart Association; WHO, World Health Organization

5.2. Pregnancy management and cardiac surgery

Pregnancy management and the timing of surgical interventions in patients with SHD during pregnancy remain medical challenges. Normal physiological pregnancy-related hemodynamic changes may aggravate the underlying cardiac disease, resulting in adverse outcomes for both mother and fetus [10]. Pregnancy management should be individualized during pregnancy based on specific clinical characteristics of valve abnormalities and maternal manifestations. It requires more detailed planning by an MDT, compared with pre-pregnancy management.

For women whose underlying cardiac disease is discovered during pregnancy, prenatal examination is indispensable. Moreover, for those diagnosed with SHD during pregnancy (include that pregnancy is unplanned), if surgery is unavoidable, every effort should be made to deliver the fetus while keeping the mother safe before open heart surgery. In non-emergency situations, the appropriate timing of cardiac surgery intervention is critical [12]. CPB surgery in the first trimester is associated with a higher tendency for fetal malformation or loss, while maternal hemodynamic changes in the third trimester increase maternal mortality [13]. The second tri-

mester is considered to be the safest time for surgical intervention for the fetus and mother. As this is a period when fetal organogenesis is basically complete, but the haemodynamic burden of pregnancy is not as its greatest period [3]. However, the maternal situation is not always ideal. For women with SHD found in the third trimester of pregnancy, given that the fetus is enough mature and cardiac procedure is estimated to complicate, simultaneous cesarean section and cardiac surgery can be carried out. That is, after cesarean section, a water sac is used to compress the uterus to reduce intraoperative and postoperative uterine bleeding, and then heart surgery is performed two hours after a cesarean section. In this study, we performed simultaneous cardiac surgery and cesarean section in two women with SHD discovery in the third trimester of pregnancy. Both mothers and fetuses survived and had good outcomes at follow-up. For the successful cesarean section of patients, open heart surgery will be generally considered in the postpartum six weeks, that is, after the puerperium. Of course, follow-up and cardiac monitoring should be maintained during this time. For patients who have had successful open-heart surgery during pregnancy and wish to continue the pregnancy, the postoperative anticoagulant regimen can be adjusted, and closely examination and cardiac monitoring as well until the time of delivery. However, it requires a comprehensive assessment of the status of the mothers and fetuses in collaboration with obstetricians and neonatologists. In three of our patients who continued their pregnancies after cardiac surgery, two patients continued their pregnancies to term and delivered healthy fetuses successfully, and another one was stillborn at 32 weeks due to intracranial hemorrhage of the fetus.

In this study, seven of the twelve patients had SHD discovered during pregnancy, and all had decompensated haemodynamic changes at the time of discovery. Of these seven patients, two delivered stillbirth, three delivered premature infants, the other two were small for gestational age infants. In addition, seven (58.3%) of the twelve patients underwent emergency surgery and none mothers dead, but there was two delivered stillbirth, two delivered premature infants, two fetal growth restriction (FGR), and one was lost to follow-up. Clearly, the fetuses had an obviously poorer outcome than mothers. More recent studies have found that cardiac surgery under CPB during pregnancy has become a relatively safe procedure for the mother, but not for the baby [14]. Continuous intensively uterine contractions during cardiac surgery and CPB are considered to be the most important factors in fetal death [13]. It reduces uterine blood flow and placental perfusion, resulting in fetal hypoxia, which can slow fetal heart rate (FHR) and even fetal death. Other secondary factors include intraoperative low blood flow, low perfusion pressure, hypothermia, prolonged aortic clamp time and CPB time. Therefore, If the gestational age is too small and the patient has a strong desire to continue the pregnancy to maximize fetal survival, a detailed MDT plan must be carried out. The FHR should be closely monitored before, during and after surgery, and certain medications (like magnesium sulfate and dexamethasone) should be used to promote fetal maturation. FHR should be emphatically monitored, especially during CPB and be maintained between 110 and 160 beats per minute [13]. It should be concerned when the FHR drops below 110 beats per minute. Meanwhile, a neonatologist should be present during surgery to deal with any unexpected situations. In the third trimester, hormones can be used to promote fetal lung development and magnesium sulfate infusion to protect the fetal nervous system [3].

Both cardiac intervention and cardiac surgery are rare during pregnancy. Most cardiac surgery during pregnancy is emergent, as patients usually have significant symptoms and manifestations of cardiovascular decompensation, which is in line with this study. In a systematic review and meta-analysis, Nivedita Jha et al suggested that poorer maternal and fetal outcomes were associated with emergency surgery, as well as NYHA classification [15]. In our cohort, the rate of emergency operation was 58.3%. In that sevens all mothers had good outcomes and only one fetal death occurred, because of our timely intervention and an MDT detailed management plan. However, according to our statistics, the hospitalization time of NYHA I-II is significantly shorter, compared with NYHA III-IV (15.3 vs. 30.8). Of the nine (n=12, 75%) NYHA grade III-IV patients, seven cases had emergency surgery, three delivered stillbirth, three delivered premature infants, one was lost to follow-up, the other two were small for gestational age infants. Early reports stated that the fetal mortality rate in NYHA grade III and IV patients was higher than 50% [13].

Maternal and fetal outcomes were related to the type of cardiac disease, secondary thoracotomy, and maternal comorbidity, in addition to nature of cardiac surgery (elective or emergency) and NAHY classification.

5.3. Postpartum Management

Follow-up monitoring after delivery is also very important to optimize maternal outcomes, with follow-up lasting at least 6 weeks after delivery. In the ROPAC study, 30% of heart failure cases occurred in the first week after delivery [16]. For those pregnant women who underwent simultaneous cardiac surgery and cesarean section, active anticoagulant treatment as soon as possible after surgery, some may need anti-infection treatment. For those who continue pregnancies after heart surgery, in addition to the above treatment, still need an MDT to develop detailed plans and closely monitor the fetus. For those who have survived cesarean section successfully, cardiac follow-up should be continued and surgical intervention should be performed after puerperium.

6. Conclusion

This study discusses the stratified management of cardiac surgery patients during pregnancy, including pre-pregnancy, pregnancy and postpartum management. Pregnancy involves a variety of car-

diovascular changes that may not be tolerated by all patients with SHD. Of course, pregnancy is also an opportunity, which may allow for the identification of undiagnosed subclinical SHD. Then this may lead to more appropriate and sustained maternal management to avoid later morbidity and mortality of mothers and fetuses. Therefore, early identification of SHD, MDT planning, proper risk assessment, indications for surgery and timing, and monitoring of uterine activity and FHR should be used to keep mothers and fetuses safe and to optimize maternal and fetal outcomes.

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8. Authors' Contributions

SL participated in the surgeries as the chief surgeon, provided data and revised the manuscript. YY and XL collected the data of patients, analyzed the data and wrote the manuscript. ZW participated in the operation and the whole treatment process, and gave suggestions on the revision of the manuscript. DC provided relevant professional support and participated in the whole treatment of patients. GW, GC, YP and XZ participated in the surgeries and in the postoperative management of the patients. GW, GC, YP and XZ contributed equally to this work.

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10. Conflict of Interest

The authors declare that they have no competing interests.

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