International Journal of Cardiology Congenital Heart Disease 1 (2020) 100049

Contents lists available at ScienceDirect

International Journal of Cardiology Congenital Heart Disease

journal homepage: www.journals.elsevier.com/international-journal-of-cardiology-congenital-heart-disease

Congenital heart disease and family planning: Preconception care, reproduction, contraception and maternal health

Karishma P. Ramlakhan [a,1], Imran Ahmed [b,1], Mark R. Johnson [b], Jolien W. Roos-Hesselink [a,*]

[a] Department of Cardiology, Erasmus University Medical Center, Rotterdam, the Netherlands
[b] Academic Department of Obstetrics and Gynaecology, Imperial College London, Chelsea and Westminster Hospital, London, United Kingdom

ARTICLE INFO

Keywords:
Congenital heart disease
Pregnancy
Reproductive health
Contraception
Maternal health
Cardiovascular disease

ABSTRACT

With the growth of the adult congenital heart disease (CHD) population, so do the considerations of reproduction, contraception and maternal health become more pressing. Fertility issues and concerns about hereditability may impact both male and female CHD patients. CHD can also influence the choice between contraceptive options, as some involve cardiovascular risks that make them less well-suited to the cardiac patient. For women with CHD, pregnancy acts as a haemodynamic stress test for the maternal cardiovascular system and often precipitates cardiac complications including heart failure, arrhythmias and thromboembolic events. For those with CHD, preconception counselling on the cardiac, obstetric and fetal risks involved in pregnancy is crucial for shared decision making and to optimize pregnancy outcomes. Risk stratification should be individualized, multidisciplinary and includes consideration of the complexity of the original CHD lesion, any residual or recurrent lesions, functional class, ventricular and valvular function, cyanosis, previous cardiac events and comorbidities, as well as the use of diagnostic modalities.

In this review, we examine reproductive concerns in CHD patients, including preconception counselling, fertility issues and hereditability of CHD. We describe the advantages and disadvantages of the currently available contraceptive options in the context of cardiac disease. We discuss general considerations in the management of pregnancy in CHD, as well as the current knowledge on the most common CHD lesions.

1. Introduction

Congenital heart disease (CHD) is the most common birth defect, affecting 9.4 out of 1000 newborns [1]. In the past decades, major improvements have been made in diagnostic modalities and in the medical, surgical and endovascular treatment of CHD, which have drastically improved survival [2]. Most patients now undergo corrective surgery at a young age and live on with a chronic heart condition, in which residual or recurrent lesions and functional limitations are prevalent and necessitate lifelong surveillance [2]. As now the adult CHD population exceeds the paediatric population, considerations of their reproductive health have become more important [3]. The presence of CHD has impact on all aspects of family planning. For both men and women with CHD, preconception counselling is relevant to address concerns on hereditability. For women, however, the consequences are more far-reaching, as cardiac disease can influence fertility, the choice between contraceptive options and pregnancy outcomes. Pregnancy itself is a major burden on the maternal cardiovascular system and may provoke cardiac complications. For the most complex forms of CHD this means that pregnancy may be contraindicated because of the risk of maternal death or severe morbidity [4].

In this review, we will discuss considerations in family planning for CHD patients, with a focus on women – although preconception counselling and hereditability are also applicable for men with CHD. We will examine reproduction, which includes fertility, hereditability and preconception care, contraception and general considerations in maternal health, as well as pregnancy outcomes for specific CHD diagnoses.

2. Reproduction

2.1. Preconception care and counselling

Pregnancy is a stress test for the maternal cardiovascular system and may provoke new-onset cardiac disease or exacerbate underlying cardiac

* Corresponding author. Erasmus University Medical Center, Department of Cardiology, Rg-435, P.O. Box: 2040, 3000, CA Rotterdam, the Netherlands.
E-mail address: j.roos@erasmusmc.nl (J.W. Roos-Hesselink).
[1] Co-first authors.

https://doi.org/10.1016/j.ijcchd.2020.100049
Received 20 July 2020; Received in revised form 15 September 2020; Accepted 27 October 2020

pathology. Conversely, the cardiac condition of a woman may also precipitate adverse pregnancy outcomes [5]. Although most women with CHD tolerate pregnancy well, in the most severe cases this combined risk can even cause maternal death. This is emphasised by the fact that cardiovascular disease is now the leading cause of maternal mortality [6].

Comprehensive multidisciplinary preconception counselling is crucial to understand the risks pregnancy may pose for an individual patient and what complications may be expected, including cardiac, obstetric and fetal. Timely discussion of contraceptive options, fertility and pregnancy are key to shared decision making. This discussion should start in the paediatric service, as sexual activity may well precede adulthood and the transition to adult services. Preconception care should also include the discussion of hereditability and the possibility of genetic counselling and testing [7].

An important tool for preconception counselling is the modified World Health Organization classification for maternal cardiovascular disease, commonly accepted as the most accurate risk assessment available for pregnancy in the context of cardiac disease (Table 1) [4]. The mWHO risk classes range from I to IV based on the corresponding expected cardiac event rate, with pregnancy being contraindicated for class IV. For women in class IV, appropriate and effective contraception is of paramount importance. The degree of cardiovascular risk is based on the complexity of the original CHD lesion, the presence of any residual or recurrent lesions, functional class, ventricular and valvular function, cyanosis and previous cardiac events [8]. Additionally, preconception counselling should take into account non-cardiac comorbidities. Pre-pregnancy evaluation should at least include an exercise test, ECG and echocardiogram, supplemented with imaging such as CT and MRI in the case of aortic pathology.

Preconception counselling also offers the opportunity to optimize the medical condition of a woman before pregnancy, which may extend to prophylactic surgery, such as is recommended for severe mitral or aortic stenosis or severe aortic dilatation [4]. Current medication should be reviewed and if necessary, teratogenic drugs (such as angiotensin-converting-enzyme inhibitors or angiotensin II receptor blockers) be replaced with safe alternatives. Preconception folic acid supplementation is advised. For women with a mechanical heart valve, a plan should be made for the anticoagulation regimen during pregnancy based on current guidelines and discussed with the patient pre-pregnancy [4]. Last but not least, women (and their partners) should be informed of the merits of optimizing their weight and being physically fit, both as a prelude to pregnancy but also long-term.

Fig. 1 summarises key moments in the life of a woman with CHD, in the context of reproductive health and family planning.

2.2. Fertility

Fertility issues are more common in women with CHD and the investigation and treatment can pose significant risks. Fertility treatment is contra-indicated in women in mWHO class IV and relatively contra-indicated in class III or those who are anticoagulated (Table 1) [4]. The referring cardiologist should highlight areas of concern and steps to avoid

Table 1
Modified World Health Organization classification of maternal cardiovascular risk for specific congenital heart disease lesions.

	mWHO I	mWHO II	mWHO II-III	mWHO III	mWHO IV
Diagnosis	Repaired ASD, VSD, PAPVR or PDA (or unrepaired small PDA) Mild valvular disease	Unrepaired ASD or VSD Repaired tetralogy of Fallot Turner syndrome without aortic dilatation	Mild LV dysfunction (EF >45%) Repaired CoA AVSD Valvular disease not in mWHO I, III or IV Marfan or HTAD (without aortic dilatation); BAV (aorta <45 mm)	Moderate LV dysfunction (EF 30–45%) Mechanical valve SRV with good/mildly impaired function Fontan circulation Unrepaired cyanotic heart disease and other complex heart disease Marfan or HTAD (aorta 40–45 mm) BAV (aorta 45–50) Turner (ASI 20–25) Tetralogy of Fallot (aorta <50 mm)	Severe systemic ventricular dysfunction (EF <30% or NYHA III–IV) SRV with moderately/severely impaired function Complicated Fontan PAH Severe mitral stenosis or severe symptomatic aortic stenosis Unrepaired severe (re-)CoA Vascular Ehlers–Danlos Marfan or HTAD (aorta >45 mm) BAV (aorta >50 mm) Turner (ASI >25) Tetralogy of Fallot (aorta >50 mm)
Risk	No detectable increased risk of maternal mortality or no/mild increase in morbidity.	Small increased risk of maternal mortality or moderate increase in morbidity	Intermediate increased risk of maternal mortality or moderate to severe increase in morbidity	Significantly increased risk of maternal mortality or severe morbidity	Extremely high risk of maternal mortality or severe morbidity
Maternal cardiac event rate	2.5–5%	5.7–10.5%	10–19%	19–27%	40–100%
Counselling	Yes	Yes	Yes	Yes, expert counselling required	Yes, pregnancy contraindicated: if pregnancy occurs, termination should be discussed
Care during pregnancy and location of delivery	Local hospital	Local hospital	Referral hospital	Expert centre for pregnancy and cardiac disease	Expert centre for pregnancy and cardiac disease
Minimal follow-up during pregnancy	Once or twice	Once per trimester	Bimonthly	Monthly or bimonthly	Monthly

ASD, atrial septal defect; ASI, aortic size index (mm/m2); AVSD, atrioventricular septal defect; BAV, bicuspid aortic valve; CoA, aortic coarctation; EF, ejection fraction; HTAD, heritable thoracic aortic disease; LV, left ventricle; MRI, magnetic resonance imaging; NYHA, New York Heart Association functional class; PAPVR, partial anomalous pulmonary venous return; PAH, pulmonary arterial hypertension; PDA, persistent ductus arteriosus; SRV, systemic right ventricle; VSD, ventricular septal defect; mWHO, modified World Health Organization classification.
Reproduced with permission from Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J et al., 2018 ESC Guidelines for the management of cardiovascular diseases during pregnancy. Eur Heart J. 2018; 39:3165–241 by permission of the European Society of Cardiology [4].

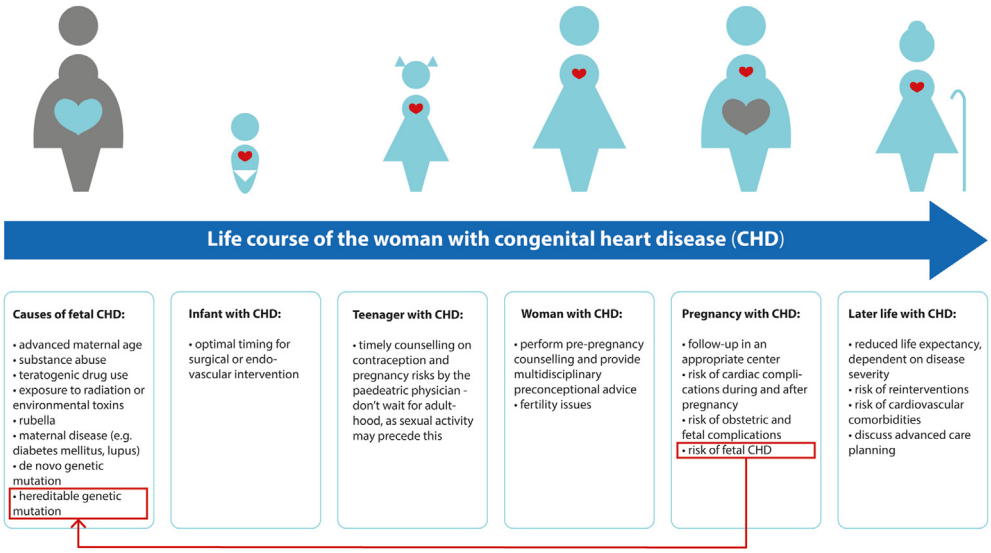

Fig. 1. Life course of the woman with congenital heart disease. CHD, congenital heart disease.

complications. For example, a vagal reaction may complicate a hysterosalpingogram, which is dangerous for those with pulmonary hypertension or a Fontan circulation, while the effects of a pneumoperitoneum and positional changes for laparoscopy can lead to significant hypoxemia, hypotension and hemodynamic instability. Superovulation alone increases the risk of thrombosis and if complicated by ovarian hyperstimulation, the risk is magnified still further along with the complications of dramatic fluid shifts. Using the lowest dose of stimulation in combination with a gonadotropin releasing hormone (GnRH) antagonist, a GnRH agonist to trigger ovulation and having a low threshold for cycle cancellation minimizes the risk. Fertility treatment such as in-vitro fertilisation (IVF) also increases the chances of multiple pregnancy, which puts greater stress on the maternal cardiovascular system, and also increases obstetric risk e.g. preterm birth. Single embryo transfer is recommended to mitigate the risk of multiple pregnancy with IVF.

Specific types of CHD have their own problems, for example, the majority of women with Turner's syndrome will require ovum donation to conceive. The process itself is low risk, but the subsequent pregnancy is more often complicated by preterm delivery, gestational hypertension/pre-eclampsia and post-postpartum haemorrhage [9]. In addition, women with Turner's syndrome are at increased risk of coarctation of the aorta and bicuspid aortic valve, associated with aortic root dilatation and an increased risk of aortic dissection (up to 2%) [10,11]. Women with a Fontan circulation have higher rates of subfertility and increased rates of miscarriage probably related to lower oxygen saturations, but also perhaps due to higher venous pressure and the tendency to form arterio-venous malformations in the uterus [12].

2.3. Hereditability

The children of parents who have CHD are at increased risk of CHD, which should be considered during pre-conception counselling. Specialist fetal echocardiography at 16 and 23 weeks is offered to identify those affected during pregnancy. The recurrence risk for non-syndromal CHD is 1–5% for paternal CHD and 2–14% for maternal CHD, and higher for syndromal CHD [7]. In some specific cases, women with 22q microdeletion, heritable aortopathies (Marfan Syndrome), the majority of heritable cardiomyopathy and heritable arrhythmogenic syndromes (Brugada syndrome), risk of transmission is as high as 50% [7]. For these women, IVF with pre-implantation genetic diagnosis (PGD) can identify an unaffected embryo for transfer.

3. Contraception

Unplanned pregnancy should be avoided in women with CHD, as it exposes the fetus to potentially teratogenic drugs and the mother to the risks of pregnancy. Careful and timely consideration of contraception options for this group is therefore critical. This should include the cardiovascular risks of the different methods of contraception and their efficacy.

It is important to consider the impact of the discussion about pregnancy on the mental health of women with CHD, particularly as these discussions should begin at a young age. There is a higher incidence of depression and anxiety amongst people living with CHD, and such discussions should be approached sensitively, bearing in mind the option of further psychological support [13].

3.1. Combined hormonal contraception

Combined hormonal contraception (CHC), which contains both oestrogen and a progestogen, comes in a variety of forms, such as vaginal ring, transdermal patch and oral medication. CHC carries an increased risk of thrombosis and hypertension, making CHC less well suited to patients with CHD [4,14]. CHC can be considered for patients who are asymptomatic, who do not require cardiac medications, and require cardiology review annually or less, but are otherwise contraindicated for patients with CHD [15].

3.2. Progesterone only contraception

Progesterone only contraception (POC) does not carry the same thrombotic and hypertensive risks as CHC [4] and is therefore a useful option for patients with CHD. Long acting reversible contraception options include the levonorgestrel intrauterine system (LNG-IUS), progestogen implant and depot medroxyprogesterone acetate (DMPA) injection. These choices offer reliable and safe contraception for people with CHD and do not require daily administration. Oral high dose POC is as effective as the CHC, but the low dose option, the “mini-pill”, is less effective and contra-indicated in those with more severe CHD where effective contraception is more important.

3.3. Non-hormonal contraception

The copper intrauterine device (IUD) is non hormonal and so offers another option for long acting reversible contraception for patients with

CHD. The copper IUD can be associated with heavier vaginal bleeding, and this could be exacerbated with CHD patients on anticoagulation, such as those with mechanical prosthetic valves [16].

The insertion of both hormonal and copper IUD may cause a vasovagal response so this should be undertaken in hospital rather than a community setting.

3.4. Permanent contraception

Surgical methods of permanent contraception can be considered in patients with CHD. Laparoscopic bilateral tubal ligation is an option if no future pregnancies are desired, but a multidisciplinary approach to surgical risk assessment, including the risks of undergoing general anaesthesia, must be undertaken and discussed with the patient. Patients with cyanotic CHD and with a univentricular heart have an increased perioperative risk, making a surgical approach relatively contraindicated [4]. Partner vasectomy may also be appropriate to discuss, depending on the patient's individual circumstances.

None of the methods discussed so far provide protection from sexually transmitted diseases and so discussions about barrier contraception use should also take place with patients with CHD, depending on the patient's individual circumstances. Should emergency contraception be required, the copper IUD, oral levonorgestrel and oral ulipristal acetate are all available options for patients with CHD [4].

Table 2 summarises the recommendations for contraceptive use for patients with CHD [15].

4. Maternal health

4.1. General considerations

Most women with CHD can safely become pregnant, but a multifactorial interplay exists between the impact of pregnancy on CHD and vice versa (Fig. 2). Extensive haemodynamic adaptations to pregnancy place considerable strain on the maternal cardiovascular system [17]. Systemic vascular resistance decreases early in the first trimester, which causes a drop in mean arterial pressure that reverses at the end of the second trimester [18]. Plasma volume increases by 45% to incompletely compensate for the drop in cardiac pre- and afterload [19]. Additionally, the heart rate increases by 15–25%, resulting in a 20–30% increase in stroke volume and a 30–50% increase in cardiac output [18,20,21]. Heart rate, blood pressure and cardiac output peak during labour, but also in the days afterwards due to the autotransfusion of the blood from the uteroplacental circulation [18,22].

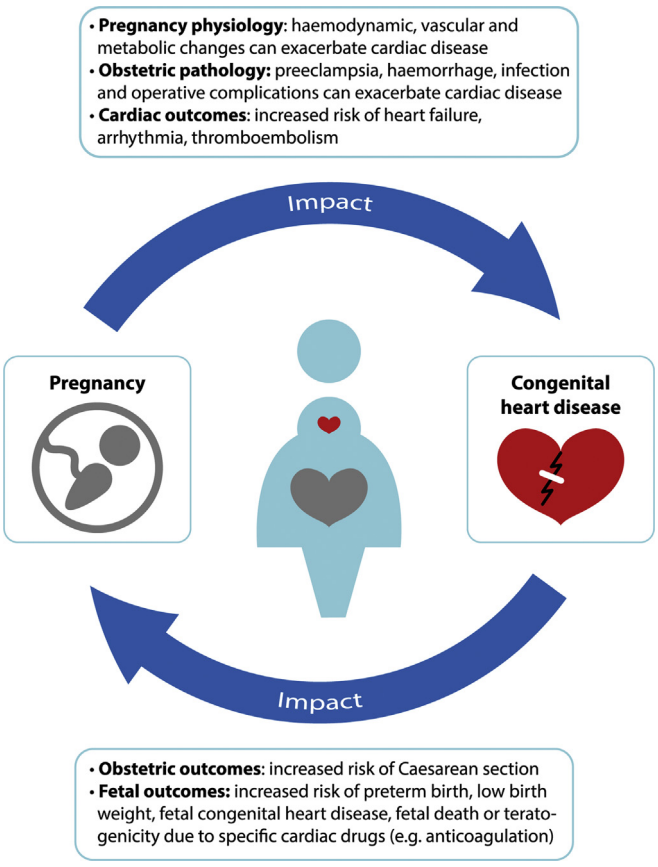

Fig. 2. The interplay between maternal congenital heart disease and pregnancy.

Additionally, common obstetric pathologies may precipitate decompensation in case of underlying cardiovascular compromise. Blood loss, infection, hypertension and fluid retention in pre-eclampsia, or acute hypotension such as during epidural or spinal analgesia can be of particular threat to women with CHD. The combined risks of physiological and pathological events make pregnancy a high-risk period for the development of cardiac complications. Although maternal mortality is relatively low at 0.1–0.2%, this is 22-fold higher compared to women without CHD [5,23]. The incidence of heart failure ranges between 5% for simple CHD and 13% for complex CHD [5]. Pregnancy increases the risk of arrhythmia (incidence 10%, OR 12 compared to women without CHD), thromboembolic events (4%, OR 2), ischemic events (0.1%, OR 35) and dissections (incidence 0.03%, OR unknown), particularly in the third trimester [5,17,23].

Conversely, CHD can also negatively affect the pregnancy itself. Caesarean section is performed in 40% of women with CHD, of which 31% are planned – despite evidence that planned Caesarean section in women with structural heart disease does not improve maternal outcome and is unfavourable for fetal outcome [5,24]. Further, CHD and (subclinical) cardiac dysfunction are suggested to relate to impaired placental perfusion and consequently, adverse pregnancy outcomes and hypertensive disorders in particular [25].

CHD is also associated with adverse fetal outcomes. Preterm birth occurs in 14–16% and up to 22–65% in complex CHD, such as cyanotic CHD [5,26]. CHD also doubles the chance of fetal growth restriction and low birth weight [23,27]. Fetal CHD is more frequent in parents with CHD and comes with a wide range of fetal and neonatal complications [7]. Use of cardiac medication is associated with fetal risks even when teratogenic drugs have been replaced before pregnancy [28]. Examples are low birth weight related to beta blocker use and miscarriages related

Table 2
Recommendations for contraceptive use for patients with congenital heart disease.

Method of Contraception	Uncomplicated CHD[a]	Complicated CHD
CHC	2	4
LNG-IUS	1	2
Progestogen only pill	1	1
Progestogen Implant	1	1
DMPA	1	1
Copper IUD	1	2

CHD, congenital heart disease; CHC, combined hormonal contraception; LNG-IUS, levonorgestrel intrauterine system; DMPA, depot medroxyprogesterone acetate; IUD, intrauterine device.
Reproduced under licence from FSRH, from the UK Medical Eligibility Criteria for Contraceptive Use 2016 (Amended 2019) [15]. ©Faculty of Sexual and Reproductive Healthcare (FRSH) 2006 to 2016.
1: No restriction to the use of the method
2: Advantages of the method generally outweigh the risks
3: Risks of the method generally outweigh the advantages; expert judgement required
4: Method presents an unacceptable risk
[a] Uncomplicated CHD defined as where the patient is asymptomatic, no cardiac medications are required, and cardiology review is required annually or less often.

to anticoagulation [27]. The long-term fetal effects of many commonly used drugs are not well-studied.

4.2. Care during pregnancy, delivery and postpartum

Table 1 describes the recommended frequency for antenatal cardiology visits, as well as the optimal location for visits and delivery according to the mWHO risk class. Cardiology visits should include an echocardiogram, ECG and regular serum measurements (e.g. for anticoagulation or NT-proBNP monitoring) as appropriate. Serial growth scans for the increased chance of fetal intra-uterine growth restriction should be performed by the obstetric caregiver, combined with specialist scans to detect inherited fetal CHD.

Ideally, before 32 weeks of gestation, a delivery plan should be agreed upon by a multidisciplinary team of caregivers, including at least a cardiologist, obstetrician and anaesthesiologist for moderate to complex heart disease, and more specialists as needed [4]. Only selected severe CHD require a Caesarean section for cardiac indications: Eisenmenger's syndrome, severe aortic stenosis, ascending aorta dilatation >45 mm, intractable heart failure and onset of spontaneous labour while on oral anticoagulants [4]. In all other cases, vaginal delivery is the preferred mode of delivery, as planned Caesarean section otherwise does not improve maternal outcome and adversely affects fetal outcome [24]. To prevent late-term complications, induction of labour is advised at 40 weeks of gestation for women with cardiac disease [4]. During labour, care should be taken to avoid sudden changes in blood pressure, such as can be observed after epidural analgesia or the oxytocin bolus postpartum [4,29]. Misoprostol, cervical ripening balloons and intravenous oxytocin are all considered safe [4,30]. Persisting vigilance is required in the postpartum period, as fluid shifts make this a high-risk period for the development of heart failure [31]. Contraception should also be discussed in the immediate postnatal period for women with CHD, so a long-term plan is made soon after giving birth.

Postnatal cardiology follow-up should take place at 6 months postpartum, earlier if necessary, and include a careful history, ECG and echocardiogram to detect any persisting functional limitations after pregnancy, or aortic dilatation in women with aortic disease. Late cardiac events occur in 6% at 1 year and 16% at 5 years postpartum and more often in women who experience an event during pregnancy (HR 3–7) [32,33].

5. Pregnancy outcomes in specific CHD

Table 1 describes the counselling requirements, mWHO class, associated cardiac event rate, optimal location and frequency of antenatal visits and optimal location of delivery for the following CHD lesions.

5.1. Shunt lesions

Pregnancy is usually well tolerated by most women with shunt lesions, which include atrial septal defect (ASD), ventricular septal defect (VSD) and atrioventricular septal defect (AVSD). Haemodynamically significant shunts should be closed before pregnancy [34]. Corrected shunt lesions class are in mWHO class I and uncorrected in class II (Table 1). Atrial arrhythmias may occur during pregnancy and in unrepaired lesions, especially ASD's, (paradoxical) thromboembolic events have been reported in up to 5% [4]. The risk of heart failure is low and only exists in women with AVSD and severe aortic valve regurgitation or impaired ventricular function. The risk of recurrent congenital heart defects in children is especially high (10%) in mothers with AVSD [35].

5.2. Pulmonary valve stenosis

Right-sided heart obstructions are generally well tolerated during pregnancy. Indeed, maternal complications such as heart failure and arrhythmias are rare in cases with a peak gradient pre-pregnancy of below 60 mmHg [36]. However, pulmonary valve stenosis is associated with an increased risk of premature labour (14%), premature delivery (15%) and intrauterine growth restriction (10%) [36]. In severe symptomatic pulmonary stenosis despite bed rest, balloon valvulotomy should be considered [37].

5.3. Aortic stenosis

There is a contraindication for pregnancy in patients with symptomatic severe left ventricular outflow tract obstruction, which includes subvalvular, valvular or supravalvular aortic stenosis and these should be corrected before pregnancy [4]. In patients with severe aortic stenosis, but without symptoms, an exercise test pre-pregnancy is advised. When the exercise test demonstrates good exercise capacity (>80%) and blood pressure response, pregnancy is usually well-tolerated but still considered high risk (mWHO III) [38]. When symptoms arise during pregnancy, bed rest is advised and if needed, balloon valvuloplasty should be considered [4,37]. Congenital aortic stenosis is often caused by a bicuspid aortic valve, which is associated with aortic dilatation and aortic dissection, meaning that measurement of aortic dimensions should be performed before and during pregnancy [39]. When the aortic diameter is > 55 mm, surgery should be considered before pregnancy [4].

5.4. Tetralogy of Fallot

Tetralogy of Fallot (ToF) consists of an overriding aorta, VSD, pulmonary stenosis and right ventricular hypertrophy. Pregnancy is usually well tolerated in patients with corrected ToF, but there is a risk of arrhythmias and heart failure, and use of cardiac medication pre-pregnancy increases the risk of complications [40]. Obstetric complications include an increased risk of fetal growth restriction and an increased risk of offspring mortality in the first year of life [4,40]. In most cases, cardiac assessment in each trimester of pregnancy is required, but more frequent assessment of cardiac function may be needed if there is severe pulmonary regurgitation or aortic dilatation (Table 1) [40].

5.5. Transposition of the great arteries

Transposition of the great arteries (TGA) involves the aorta arising from the right ventricle and the pulmonary artery arising from the left ventricle. This is repaired with either an atrial switch operation, or the more recent arterial switch procedure. Previous atrial switch carries an increased risk of complications in pregnancy compared with the arterial switch, where the risks of pregnancy seem low although few data are available [4]. Pregnancy complications in TGA with atrial switch include arrhythmias and worsening systemic ventricular function with ensuing tricuspid regurgitation [41]. Obstetric complications include a 38% incidence of both preterm birth and small-for-gestational-age babies [41]. Congenitally corrected TGA also carries risks in pregnancy, including A-V block and an irreversible decline in right ventricular function, and so close monitoring, including monthly echocardiograms, is recommended [4].

5.6. Aortopathy

Pregnancy in women with aortopathy carries a risk of aortic dissection. Both Marfan and Loeys-Dietz syndromes are heritable aortopathies and pregnancy may be contraindicated depending on the diameter of the ascending aorta (Table 1). In both conditions, pregnancy is not recommended if the ascending aorta is greater than 45 mm [4]. However, it is important to note that dissection can also occur with a normal aortic diameter. Pregnancy with Marfan syndrome additionally carries an increased risk of cardiac complications, such as left ventricular dysfunction, and obstetric complications, of which postpartum haemorrhage is the most common [42]. There is an increased incidence of small-for-gestational-age babies [42]. Management in pregnancy consists

of close surveillance of aortic root dimensions and cardiac function, strict blood pressure control and serial ultrasound scans for fetal growth [4]. In the absence of concerns regarding aortic root dilatation or cardiac function, vaginal birth is possible. Monitoring for aortic root dilatation should continue for 6 months postpartum as the risk of dissection extends significantly into the postnatal period, which justifies imaging before discharge after delivery in women with aortic dilatation >40 mm.

Vascular Ehlers-Danlos syndrome is another condition with increased risk of aortic dissection, as well as obstetric risks such as uterine rupture, anal sphincter injuries and preterm birth [43]. Vascular Ehlers-Danlos is mWHO class IV and pregnancy is therefore contra-indicated, as pregnancy related mortality is greater than 5% [43]. Pregnancies in women with Loeys-Dietz syndrome are also considered very high risk and again careful counselling before embarking on pregnancy is needed [44].

5.7. Fontan circulation

In a Fontan circulation there is a single functional ventricle, which may be the outcome of repair for a variety of congenital cardiac defects such as hypoplastic left heart syndrome, pulmonary atresia with intact septum, and double inlet ventricle. As previously discussed, fertility can be reduced in women with Fontan circulation, and once pregnancy occurs, the miscarriage risk is 27% [45]. Thromboembolism is a significant risk in Fontan circulation and so therapeutic anticoagulation throughout pregnancy is recommended [4]. Atrial arrhythmia is the most common cardiac complication in pregnancy and may require electrical cardioversion [45]. Obstetric risk includes a very high incidence of preterm birth at 69% [45]. Management involves counselling against pregnancy for patients in modified WHO class IV, and monthly follow up continuing into the first few weeks of the postnatal period for patients who do get pregnant [4].

5.8. Cyanotic lesions

In women with cyanosis the most important prognostic factor for maternal outcome is the presence or absence of pulmonary hypertension. Impaired ventricular function and valve lesions are also common and should be taken into account when establishing the pre-pregnancy risk, which is typically mWHO class III, but can be class IV in case of pulmonary hypertension or reduced ventricular function [46]. Cyanotic lesions have a highly significant impact on fetal outcome: maternal arterial oxygen saturation <90% is associated with fetal growth restriction and premature delivery occurs in up to 50–70% of pregnancies; maternal arterial oxygen saturation <85% is associated with a minimal chance of live birth (12%) and pregnancy should therefore be discouraged [47]. A pre-pregnancy exercise test with oxygen measurements is recommended, because if oxygen saturations decrease significantly during the exercise test, pregnancy has a poor prognosis and should probably be discouraged [4].

6. Conclusions

Timely discussions on reproductive health will aid the CHD patient and their physician in shared decision making. Concerns about hereditability are relevant for both men and women with CHD and may require genetic counselling. Fertility issues are more common in CHD and assisted reproductive technology can be of benefit, but cardiovascular risks of investigation and treatment should be considered. The relative merits of contraceptive options should be considered in the context of CHD and the particular patient. Preconception care should include an individualized estimation of cardiac, obstetric and fetal risks of pregnancy, with the appropriate use of diagnostic modalities to assess functional status and implications for pregnancy outcomes. Pregnancy is tolerated well by most women with CHD, albeit they have an increased risk of death, cardiac complications such as heart failure and thromboembolism, obstetric complications such as Caesarean section and fetal complications such as preterm labour, low birth weight and fetal CHD. Specialist care by a multidisciplinary team in a centre that is appropriate for the complexity of the woman's CHD is key to a safe pregnancy and optimal outcomes.

Sources of funding

None.

Declarations of competing interest

None.

References

[1] Liu Y, Chen S, Zühlke L, et al. Global birth prevalence of congenital heart defects 1970-2017: updated systematic review and meta-analysis of 260 studies. Int. J. Epidemiol. 2019;48:455–63.
[2] Khairy P, Ionescu-Ittu R, Mackie AS, Abrahamowicz M, Pilote L, Marelli AJ. Changing mortality in congenital heart disease. J. Am. Coll. Cardiol. 2010;56:1149–57.
[3] Marelli AJ, Ionescu-Ittu R, Mackie AS, Guo L, Dendukuri N, Kaouache M. Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010. Circulation 2014;130:749–56.
[4] Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J, et al. ESC Guidelines for the management of cardiovascular diseases during pregnancy. Eur. Heart J. 2018;39:3165–241. 2018.
[5] Roos-Hesselink J, Baris L, Johnson M, et al. Pregnancy outcomes in women with cardiovascular disease: evolving trends over 10 years in the ESC Registry of Pregnancy and Cardiac disease (ROPAC). Eur. Heart J. 2019:1–8.
[6] Creanga AA, Syverson C, Seed K, Callaghan WM. Pregnancy-related mortality in the United States, 2011-2013. Obstet. Gynecol. 2017;130:366–73.
[7] Pierpont ME, Brueckner M, Chung WK, et al. Genetic basis for congenital heart disease: revisited: A scientific statement from the American heart association. Circulation 2018;138:e653–711.
[8] Silversides CK, Grewal J, Mason J, et al. Pregnancy outcomes in women with heart disease: the CARPREG II study. J. Am. Coll. Cardiol. 2018;71:2419–30.
[9] Nejdet S, Bergh C, Källén K, Wennerholm UB, Thurin-Kjellberg A. High risks of maternal and perinatal complications in singletons born after oocyte donation. Acta Obstet. Gynecol. Scand. 2016;95:879–86.
[10] Carlson M, Silberbach M. Dissection of the aorta in Turner syndrome: two cases and review of 85 cases in the literature. BMJ Case Rep. 2009;2009:bcr0620091998.
[11] Karnis MF, Zimon AE, Lalwani SI, Timmreck LS, Klipstein S, Reindollar RH. Risk of death in pregnancy achieved through oocyte donation in patients with Turner syndrome: a national survey. Fertil. Steril. 2003;80:498–501.
[12] Cauldwell M, Steer PJ, Bonner S, et al. Retrospective UK multicentre study of the pregnancy outcomes of women with a Fontan repair. Heart 2018;104:401–6.
[13] Awaad MI, Darahim KE. Depression and anxiety in adolescents with congenital heart disease. Middle East Current Psychiatry 2015;22:2–8.
[14] Lidegaard O, Lokkegaard E, Svendsen AL, Agger C. Hormonal contraception and risk of venous thromboembolism: national follow-up study. BMJ 2009;339:b2890.
[15] The Faculty of Sexual and Reproductive Healthcare. UK medical eligibility for contraceptive use (amended 2019). UKMEC 2016:1–170.
[16] Hubacher D. Copper intrauterine device use by nulliparous women: review of side effects. Contraception 2007;75:S8–11.
[17] Ramlakhan KP, Johnson MR, Roos-Hesselink JW. Pregnancy and cardiovascular disease. Nat. Rev. Cardiol. 2020:1–14.
[18] Duvekot JJ, Peeters LL. Maternal cardiovascular hemodynamic adaptation to pregnancy. Obstet. Gynecol. Surv. 1994;49:S1–14.
[19] de Haas S, Ghossein-Doha C, van Kuijk SM, van Drongelen J, Spaanderman ME. Physiological adaptation of maternal plasma volume during pregnancy: a systematic review and meta-analysis. Ultrasound Obstet. Gynecol. 2017;49:177–87.
[20] Meah VL, Cockcroft JR, Backx K, Shave R, Stohr EJ. Cardiac output and related haemodynamics during pregnancy: a series of meta-analyses. Heart 2016;102:518–26.
[21] Hunter S, Robson SC. Adaptation of the maternal heart in pregnancy. Br. Heart J. 1992;68:540–3.
[22] Robson SC, Dunlop W, Boys RJ, Hunter S. Cardiac output during labour. Br. Med. J. 1987;295:1169–72.
[23] Thompson JL, Kuklina EV, Bateman BT, Callaghan WM, James AH, Grotegut CA. Medical and obstetric outcomes among pregnant women with congenital heart disease. Obstet. Gynecol. 2015;126:346–54.
[24] Ruys TP, Roos-Hesselink JW, Pijuan-Domenech A, et al. Is a planned caesarean section in women with cardiac disease beneficial? Heart 2015;101:530–6.
[25] Pieper PG, Balci A, Aarnoudse JG, et al. Uteroplacental blood flow, cardiac function, and pregnancy outcome in women with congenital heart disease. Circulation 2013;128:2478–87.
[26] Drenthen W, Pieper PG, Roos-Hesselink JW, et al. Outcome of pregnancy in women with congenital heart disease: a literature review. J. Am. Coll. Cardiol. 2007;49:2303–11.

[27] van Hagen IM, Roos-Hesselink JW, Donvito V, et al. Incidence and predictors of obstetric and fetal complications in women with structural heart disease. Heart 2017;103:1610–8.
[28] Ruys TP, Maggioni A, Johnson MR, et al. Cardiac medication during pregnancy, data from the ROPAC. Int. J. Cardiol. 2014;177:124–8.
[29] Svanstrom MC, Biber B, Hanes M, Johansson G, Naslund U, Balfors EM. Signs of myocardial ischaemia after injection of oxytocin: a randomized double-blind comparison of oxytocin and methylergometrine during Caesarean section. Br. J. Anaesth. 2008;100:683–9.
[30] Ramsey PS, Hogg BB, Savage KG, Winkler DD, Owen J. Cardiovascular effects of intravaginal misoprostol in the mid trimester of pregnancy. Am. J. Obstet. Gynecol. 2000;183:1100–2.
[31] Ruys TP, Roos-Hesselink JW, Hall R, et al. Heart failure in pregnant women with cardiac disease: data from the ROPAC. Heart 2014;100:231–8.
[32] Kampman MA, Balci A, Groen H, et al. Cardiac function and cardiac events 1-year postpartum in women with congenital heart disease. Am. Heart J. 2015;169:298–304.
[33] Balint OH, Siu SC, Mason J, et al. Cardiac outcomes after pregnancy in women with congenital heart disease. Heart 2010;96:1656–61.
[34] Yap SC, Drenthen W, Meijboom FJ, et al. Comparison of pregnancy outcomes in women with repaired versus unrepaired atrial septal defect. Bjog 2009;116:1593–601.
[35] Drenthen W, Pieper PG, van der Tuuk K, et al. Cardiac complications relating to pregnancy and recurrence of disease in the offspring of women with atrioventricular septal defects. Eur. Heart J. 2005;26:2581–7.
[36] Hameed A, Karaalp IS, Tummala PP, et al. The effect of valvular heart disease on maternal and fetal outcome of pregnancy. J. Am. Coll. Cardiol. 2001;37:893–9.
[37] Nishimura RA, Otto CM, Bonow RO, et al. AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American college of cardiology/American heart association task force on practice guidelines. J. Am. Coll. Cardiol. 2014;63:e57–185. 2014.
[38] Orwat S, Diller GP, van Hagen IM, et al. Risk of pregnancy in moderate and severe aortic stenosis: from the multinational ROPAC registry. J. Am. Coll. Cardiol. 2016;68:1727–37.
[39] Immer FF, Bansi AG, Immer-Bansi AS, et al. Aortic dissection in pregnancy: analysis of risk factors and outcome. Ann. Thorac. Surg. 2003;76:309–14.
[40] Balci A, Drenthen W, Mulder BJ, et al. Pregnancy in women with corrected tetralogy of Fallot: occurrence and predictors of adverse events. Am. Heart J. 2011;161:307–13.
[41] Cataldo S, Doohan M, Rice K, Trinder J, Stuart AG, Curtis SL. Pregnancy following Mustard or Senning correction of transposition of the great arteries: a retrospective study. BJOG 2016;123:807–13.
[42] Curry RA, Gelson E, Swan L, et al. Marfan syndrome and pregnancy: maternal and neonatal outcomes. BJOG 2014;121:610–7.
[43] Murray ML, Pepin M, Peterson S, Byers PH. Pregnancy-related deaths and complications in women with vascular Ehlers-Danlos syndrome. Genet. Med. 2014;16:874–80.
[44] Frise CJ, Pitcher A, Mackillop L. Loeys-Dietz syndrome and pregnancy: the first ten years. Int. J. Cardiol. 2017;226:21–5.
[45] Gouton M, Nizard J, Patel M, et al. Maternal and fetal outcomes of pregnancy with Fontan circulation: a multicentric observational study. Int. J. Cardiol. 2015;187:84–9.
[46] Ladouceur M, Benoit L, Basquin A, et al. How pregnancy impacts adult cyanotic congenital heart disease: a multicenter observational study. Circulation 2017;135:2444–7.
[47] Presbitero P, Somerville J, Stone S, Aruta E, Spiegelhalter D, Rabajoli F. Pregnancy in cyanotic congenital heart disease. Outcome of mother and fetus. Circulation 1994;89:2673–6.