

Managing Cardiac Emergencies in Pregnancy

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Learning objectives (3):

- Optimal management of cardiac emergencies during pregnancy
- Developing a delivery plan for pregnant women with an acute cardiac complication
- To understand that the knowledge base is limited to expert opinion and experience, or observational cohort studies. There are no randomized trials.

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Introduction

Reducing maternal mortality was a major component of the fifth millennium development goal. A drop of 47%, was achieved mainly through reductions in sepsis and haemorrhage.[1] Maternal mortality due to cardiovascular causes has not decreased and in developed countries there even seems to be a tendency to increase.[2, 3] These women typically die due to cardiac emergencies like aortic dissection, acute coronary syndrome or heart failure.

Pregnancy is characterised by a substantial haemodynamic challenge and hence, in women with known cardiac disease, the most common cardiovascular complication during pregnancy is heart failure.[4] In others, who present for instance with aortic dissection, a cardiac diagnosis may not have been known before.

Preconception counselling by an experienced team of specialists is essential in order to estimate the risk of, and anticipate to, eventual cardiac complications in women with known cardiac disease. This is based on a combination of history, physical examination, VO₂ max exercise testing, echocardiography and in some cases cardiac CT or MR. During counselling the potential implications of the cardiac condition on pregnancy outcome are also addressed.

Careful evaluation of maternal risks can be based on several risk tools.[5-7] Of these, the modified World Health Organization (WHO) risk stratification model seems the best predictor of risks. Women in modified WHO class IV (a severely dilated aorta, pulmonary hypertension, severe systemic ventricular dysfunction, symptomatic left heart obstruction) are at such high risk of severe complications that they should be advised against pregnancy.

In women who present in pregnancy with a major cardiac event, early recognition of symptoms is important. Treatment is based on the underlying problem and prompt referral to a specialised center is strongly recommended. The maternal and fetal condition both determine further decisions in choosing a conservative or invasive approach. However, in life-threatening circumstances the mother always prevails. This strategy usually also serves in the best interest of the fetus.

In this review, the most common acute cardiac complications during pregnancy are discussed. The incidence, diagnostics, and considerations regarding medication and intervention are outlined. A summary flow chart for practical use is provided for each complication.

Heart failure

Incidence and timing

In two large prospective cohorts of pregnant women with cardiac disease, heart failure was the most

common cardiac complication[4, 6] and in the largest study it was the most important reason of cardiac death.[8] The prevalence varies per cardiac condition. In a review of series and case reports, the occurrence of heart failure ranged from 4.8% in women with congenital heart disease in general, to more than 21.1% in patients with Eisenmenger disease.[9] In prospective studies of patients with any cardiac disease the prevalence is as high as 13.1%,[4] with highest prevalence in women with shunt lesions, diminished cardiac function and pulmonary hypertension (41%). Other patients at particular risk are those with a left heart obstruction.[10-13] [8, 14] [5, 15] [8] In patients with congenital heart disease and a baffle or conduit in situ, prosthesis related problems as an underlying cause should be ruled out.

Heart failure typically occurs at the end of the second trimester or directly postpartum. At the end of the second trimester the cardiac adaptation with rise in cardiac output and plasma volume reaches its maximum[16], while uterine contractions are accompanied by brisk rises in cardiac output, and immediately postpartum a volume overload occurs by autotransfusion of the uteroplacental volume in the maternal circulation. These physiological mechanisms may explain the timing of heart failure, as summarised in **Figure 1**. [8, 16, 17] The timing of heart failure is different among the underlying cardiac diagnoses. While shunt lesions (atrial and ventricular septal defects) show a peak incidence of heart failure by the end of the second trimester, cardiomyopathies and stenotic lesions more often manifest at the end of pregnancy and postpartum.[8]

NT-proBNP is predictive of cardiovascular events during pregnancy, but is also elevated in pre-eclamptic women without any cardiac abnormality, which is probably attributable to the pressure overload and cardiac dysfunction.[18-20] Therefore a low NT-proBNP has a high negative predictive value, but a high value does not have a high predictive value. There is a remarkable association between pre-eclampsia and heart failure. A study assessing cardiac function by cardiac ultrasound in patients with either preterm or term pre-eclampsia and normotensive controls showed signs of diastolic and systolic ventricular dysfunction mainly in women with preterm pre-eclampsia which is often the severe form.[21] Concurrently, 30% of cardiac patients suffering from pre-eclampsia, also developed heart failure during pregnancy.[8] Whether the (subclinical) cardiac dysfunction is the cause, result or combination of both of defective adaptation and malplacentaion leading to generalised endothelial dysfunction in severe early onset pre-eclampsia remains controversial and needs further investigation.[22, 23]

Management (Figure 2)

An experienced center from Germany published their management algorithm as used for patients with acute heart failure.[24] A multidisciplinary team gathers within 15 minutes after admission and

decides on further management based on the maternal and fetal condition and prognosis. In case of a viable fetus, the choice of immediate delivery or continuing pregnancy with heart failure therapy according to the guidelines is based on parents wish and maternal and fetal condition.[5] In case of a non-viable fetus, maximum heart failure therapy is administered directly.

In case of acute heart failure bedrest is advised. A few exceptions taken, pharmacological management of acute heart failure during pregnancy is according to the guidelines for treatment in non-pregnant patients.[25, 26] This should always be done in cooperation with the obstetrician. Diuretics can be given for congestive symptoms, and are considered safe during pregnancy.[27] Dosage should be increased with caution, to avoid intravascular volume depletion. ACE inhibitors and angiotensin receptor blockers are contraindicated during the first, second and third trimester of pregnancy due to their fetotoxic effects[28] and can only be used in exceptional circumstances as stated by the FDA (category D). Instead, hydralazine and nitrates are considered as alternatives for afterload reduction.[29] Low dose beta-blockers can be considered in case of sinus-tachycardia or hypertension. Inotropic therapy can be considered in those who are continuously haemodynamically unstable: dopamine and levosimendan are then first choice agents, although evidence on efficacy and safety in pregnant women is limited and controversial.[5, 30, 31] In patients with ventricular dysfunction and consequently a cardiac thrombus or systemic emboli, therapeutic anticoagulation is recommended, preferably with either low molecular weight heparin or unfractionated heparin with adequate and strict monitoring of coagulation. Sinus rhythm should be aimed for in all patients with heart failure. Extensive information about cardiac medication has been given by the ESC guidelines on management of cardiovascular disease during pregnancy.[5]

If the pharmacological treatment achieves stabilization of the maternal condition, a vaginal delivery is preferred as close as possible to term. A caesarean section does not seem to be protective or less strenuous for the cardiac condition in most women with cardiac disease.[32, 33] However, in individual cases CS might be considered, especially in those women with further deterioration in cardiac function, in whom it is believed that the heart function is such that it may not cope with the strain of substantial fluctuations in cardiac output accompanying contractions during delivery.[5] Because of the large volume shifts shortly after delivery, women with a history of heart failure should still be monitored intensively for at least 48 hours after delivery.

Heart failure in patients with pulmonary hypertension

In patients with heart failure due to pulmonary arterial hypertension, in addition to treating the congestive symptoms, treatment with pulmonary vasodilators should be considered to lower the pulmonary pressure. Some of these agents have teratogenic effects, in particular endothelin receptor

antagonists, and are contraindicated. Experience with the use of other advanced pulmonary arterial hypertension therapies during pregnancy is limited, but the use of prostanoid therapy and PDE5 inhibitors in the current era seem to be associated with improved maternal survival during pregnancy.[34] Nitric oxide (NO) inhalation treatment may cause a fast decrease in pulmonary vascular resistance, and the use in parturients has been reported with a maternal survival of 68%, often administered as a final course of action.[35-37] A decision on mode of delivery in these women should be individualised. During caesarean section, the anaesthetic approach should include efforts to prevent major haemodynamic changes, and the use of oxytocin should be restricted. Systemic vascular resistance can be maintained by the use of low-dose phenylephrine or nor-adrenaline.[38] An experienced cardioanaesthetist is essential.

Heart failure in patients with peripartum cardiomyopathy

In women who present with congestive symptoms, a diminished left ventricular function and no history of a cardiac diagnosis in the last month of pregnancy or first months after delivery, peripartum cardiomyopathy should be considered as the underlying diagnosis. It is a diagnosis of exclusion and is probably related to dilated cardiomyopathy. Prolactin has been advocated to play an important role in the pathophysiology.[39, 40] Heart failure treatment is not different from the strategy in other pregnant patients, but in addition, bromocriptine is a promising agent. Bromocriptine is a dopamine-2D agonist that inhibits prolactin secretion, and in small studies it has shown to improve left ventricular function.[41, 42] Its efficacy is currently being investigated in a randomised controlled trial.[41]

Arrhythmias

Supraventricular tachycardia (Figure 3)

Palpitations, but also dizziness and (near)syncope, may occur during normal pregnancy and are mostly benign: only 10% of symptomatic episodes are actually caused by arrhythmia.[43] In women with an arrhythmic event before pregnancy, recurrence rate of supraventricular arrhythmia during pregnancy is approximately 50%.[44] The occurrence of new onset symptomatic supraventricular tachycardia during pregnancy is rare. An incidence of 1.3% has been reported in women with cardiac disease. In pregnant women without cardiac history the incidence of supraventricular arrhythmia is presumably much lower, and mainly described in case reports and occurs often in the third trimester.[45] The workup in new onset atrial fibrillation is the same as outside pregnancy: after careful history and physical examination, an ECG, serum electrolytes and thyroid function, and an echocardiography should be performed to assess any possible predisposing or underlying abnormality.

Guidelines recommend considering each antiarrhythmic agent as potentially fetotoxic.[5] Also, the physiological haemodynamic changes during pregnancy influence the pharmacokinetics of the agents, warranting dose adjustment in pregnant women. Like outside pregnancy, treatment depends on the maternal condition, duration of the arrhythmia and whether the hemodynamic condition is stable or not. The majority of suggested therapies is based on observational data. An extensive overview has been given by Tan and Lie in 2001.[46] Treatment recommendations are summarised in **Figure 3**.

In case of an atrioventricular (nodal) re-entrant tachycardia, the first intervention is a vagal manoeuvre and if ineffective followed by adenosine. Both are reported to be safe in pregnancy.[47, 48] Atrial tachycardia, including intra-atrial re-entry tachycardia, may also be treated with adenosine and if unsuccessful, a beta-blocker or digoxin can be started as rate control. Most beta-blockers are FDA category C, except for atenolol, which is marked as category D, and should be avoided.

In atrial fibrillation, sotalol is considered FDA class B and can be used for rhythm control. Alternatives are intravenous ibutilide[49] or flecainide (FDA class C). In haemodynamic unstable patients or if pharmacological cardioversion failed, immediate direct current cardioversion should be performed, which is generally considered safe during pregnancy. In any case, cardioversion should be done under strict fetal and maternal monitoring and with an obstetric team and facilities standby for immediate emergency caesarean section if necessary.[50]

Agents that are not first choice treatment but can be considered because of their effectiveness outside pregnancy are: amiodarone (only short-term use, FDA D),[51] procainamide (FDA C, limited experience), propafenon (FDA C, limited experience), and verapamil (FDA C, risk of maternal hypotension and subsequent placental hypoperfusion).

The indications for anticoagulant therapy are the same for pregnant women with supraventricular arrhythmias as for non-pregnant patients.[52] Pregnancy and the puerperium are a thrombogenic state and should be considered as an extra thromboembolic risk factor. Vitamin K antagonists (VKA, FDA category D) should preferably be stopped as soon as pregnancy is confirmed, because of the teratogenic risk, especially between weeks 6-9 and when high doses are needed.[53, 54] This can be replaced by (low molecular weight) heparin (LMWH, FDA category B). There is hardly any evidence on the safety of new oral anticoagulation (NOAC) therapy during pregnancy. In rats, most of the NOACs cross the placenta, and therefore NOACs should not be used, although short-term use of rivaroxaban in the first trimester did not reveal severe problems in the short term.[55]

Ventricular tachycardia

Although ventricular arrhythmia's are probably even rarer than supraventricular tachycardia's, they

are potentially associated with more detrimental consequences. The incidence of ventricular tachycardia in women with cardiac disease is approximately 1.0-1.4%. [6, 56] The influence of pregnancy on catecholamine levels might play a role in the pathophysiological mechanism. These catecholamine induced tachycardia's appeared sensitive to beta-blockers. [57] In channelopathies such as Brugada syndrome, the trigger seems to be more hormone related. [58] A ventricular arrhythmia in the third trimester or postpartum period in previously healthy women, may also be the first presentation of peripartum cardiomyopathy. [59, 60] A remarkable reduced risk of events in long QT syndrome has been observed during the course of pregnancy, whilst the postpartum period seems to be associated with an increased risk. [61] [62] [63]

In all patients the main target of treatment is to retrieve or maintain haemodynamic stability, for the benefit of the mother, and by doing so also for the fetus. In a haemodynamically unstable patient with any type of ventricular tachycardia, immediate defibrillation is indicated. [64] If a patient is stable, chemical cardioversion can be considered. First choice drug in women who have a monomorphic ventricular tachycardia, without signs of long-QT syndrome, is IV sotalol (FDA B) or procainamide (FDA C). [65] In case of sustained refractory or recurrent ventricular tachyarrhythmias, not directly responding to defibrillation, IV amiodarone is an alternative .

In patients with idiopathic right ventricular outflow tract tachycardia, which is probably the most common ventricular arrhythmia in otherwise healthy pregnant women, verapamil or beta-blockers are usually effective [46] to prevent recurrent episodes. Therapeutic management of ventricular arrhythmias is further summarised in **Figure 4**. [66, 67]

In patients with poorly tolerated and drug resistant tachyarrhythmia's, radio frequency ablation can be considered. Evidence on safety during pregnancy is lacking and based on case reports. General advice is to perform ablation in the second trimester if possible and with ultrasound assistance, to minimise the potential influence of radiation on fetal organogenesis. [64, 68] Limited experience with an implantable cardioverter-defibrillator (ICD) during pregnancy revealed no major problems. [69-71] Reports of experience with ICD implantation during pregnancy are lacking, but a subcutaneous ICD is a promising technique as fluoroscopy is no longer required. [64]

Resuscitation

Several guidelines provide practical advices concerning the treatment of maternal cardiac arrest, which are summarised in **Table 1**. [72, 73]

Immediate basic life support and, when available, advanced life support should be initiated as in non-pregnant persons. In order to make chest compressions effective it is important to relieve aorticaval

compression once pregnancy has progressed beyond 20 weeks by left lateral manual displacement of the gravid uterus or by putting a wedge under her right side. If resuscitation is not successful by 4 minutes, emergency perimortem caesarean section is advised on site and delivery achieved within the minute on maternal indication. The main aim of this procedure is to increase the chances of successful resuscitation by effectively relieving aortocaval compression and creating a sudden autotransfusion with the blood that was stored in the uteroplacental circulation. As an additional benefit it increases fetal survival as the uteroplacental perfusion is poor during arrest and chest compressions.[74, 75] The uterus is considered a non-essential organ and not perfused.

The position of chest compressions has been recently studied. The authors stated that the previously suggested higher sternal position of the hands during pregnancy is based on the presumption that the maternal heart is positioned superiorly in the third trimester.[76] However, an MRI in 34 pregnant females, showed no significant displacement of the heart. Therefore, there is no need to adjust the hand position. The outcome of cardiopulmonary resuscitation during pregnancy has been described by a population-based cohort study from Canada. The authors reported a survival of 36.9%, which was better than the survival in matched non-pregnant women.[77]

Acute Myocardial Infarction

An acute myocardial infarction (AMI) occurs 3 to 4 times more often during pregnancy than in non-pregnant women of the same age.[78] The incidence ranges in population-based studies from 1:35,700 [79] to a more recent estimation of 1:17,000 [78] with a maternal mortality rate of 5-7%. [80] [81, 82] At highest risk of AMI are pregnant women of older age, in particular those >40 years, women with a history of pre-eclampsia and women with cardiovascular risk factors, such as smoking and diabetes.[78, 79] Patients with known ischemic heart disease have a 10% risk of a cardiac event (cardiac arrest, heart failure, acute coronary syndrome, or ventricular arrhythmia) in a subsequent pregnancy.[83]

Diagnostics

The first presentation of an acute myocardial infarction may be a cardiogenic shock (38%) or with a ventricular arrhythmia (12%).[80] First assessment of patients suspected for an acute coronary syndrome should be similar as in non-pregnant patients. Time to intervention is as important in pregnant women with an ST-elevation myocardial infarction (STEMI) as in non-pregnant patients, and therefore, an ECG should be made directly. Cardiac markers may also reveal the diagnosis, whether or not supported by echocardiography to investigate wall motion abnormalities. Troponin I is generally not influenced by pregnancy or pre-eclampsia and therefore an elevated level is highly

suspicious of an AMI.[84-86] Imaging of the underlying coronary anatomy is key in the further therapeutic approach of a STEMI. An urgent coronary angiography should therefore be performed and is not associated with high rates of fetal radiation exposure, but iatrogenic dissections have been reported. The most common diagnosis is an acute coronary dissection.[87] In a review of literature between 2006 and 2011, the angiogram showed: coronary dissection in 43% (mainly postpartum); atherosclerosis in 27%; coronary thrombus in 17% (both mainly in second or third trimester); normal in 9%; vasospasm in 2%; tako tsubo in 2% (postpartum) of AMI.[80] Because of the risk of dissection induction, a non-invasive approach has been advocated as an alternative in stable and low-risk women with a Non-ST-elevation myocardial infarction.

Treatment of myocardial infarction

Treatment of pregnant women with an AMI depends on the aetiology and is further delineated in **Figure 5**. In case of a coronary dissection, thrombolysis should be avoided because of the local bleeding risks which might worsen the situation.[80] [88] [89] Percutaneous coronary intervention (PCI) is the first choice of therapy, as it is in case of atherosclerosis. A PCI does induce fetal radiation exposure, but even in difficult procedures the potential benefits outweigh the risks.[90] If possible, balloon angioplasty may be considered, because knowledge on antiplatelet therapy such as clopidogrel in pregnancy is limited (FDA class B). The use of low dose aspirin is safe. There is a lack of experience with Glycoprotein IIb/IIIa during pregnancy, and thus it should be avoided. Nitrates are widely used in pregnant women for tocolysis and have proven to be safe.[91] Nifedipine is the calcium antagonist that has been used most frequently during pregnancy for hypertension and tocolysis[92] and is the drug of choice in women with vasospasm associated complaints. Statins are contraindicated during pregnancy (FDA class X).

Coronary artery bypass grafting (CABG) is associated with high fetal loss, and should preferably be performed after delivery if the fetus is viable. Cardiac surgery during pregnancy has mainly been reported in valvular or aortic disease while CABG experience consists of case reports only.[81] When unavoidable, the second trimester is probably the safest period, and surgery is best performed in left lateral position in normothermic condition with high pump flow.

In patients with a coronary thrombus, thrombolysis may be considered. The available evidence of thrombolysis during pregnancy for myocardial infarction is limited,[88] and is mainly based on the use of recombinant tissue plasminogen activator. Most experience during pregnancy for other reasons than AMI, concerns the use of streptokinase.[89]

After the course of a successfully treated ischemic event during pregnancy, the preferred mode of delivery is vaginal, with caesarean section reserved for obstetric reasons.[93, 94]

Aortic dissection

Incidence

Pregnancy induces not only haemodynamic changes, but also influences the integrity of the vessel wall. A morphological study showed marked fragmentation of reticular fibres in the tunica media of the aorta in pregnant women without aortic disease.[95] Also, smooth muscle cells in the aortic media were subject to both hypertrophy and hyperplasia, compared to non-pregnant women. These adaptations are usually well tolerated by healthy women: the incidence of aortic dissection in women of reproductive age is low (0.4 per 100,000 person years).[96] But women with aortic disease are at increased risk of aortic dilatation and aortic dissection. It is the most important cause of cardiac maternal death in the UK.[2]

At high risk are women with Marfan syndrome, an autosomal dominant connective tissue disease, with a reported rate of pregnancy-related aortic dissection of up to 4.5% in prospective studies,[97-99] and up to 6.4% in retrospective studies.[100-104] Other diseases that need careful preconception counselling and follow-up, are women with Loeys-Dietz,[105] vascular type Ehlers Danlos,[106] *SMAD3* mutation or Aneurysm Osteoarthritis Syndrome,[107, 108] *ACTA2* mutation,[109] *TGF β 3* mutation,[110] unspecified familial thoracic aortic aneurysm and dissection syndrome, Turner syndrome[111, 112] and bicuspid aortic valve.[113] Studies reporting vascular complications during pregnancy in these women are scarce and small; the largest studies included mainly women with Marfan syndrome. Important and independent risk factors are initial aortic size and rate of diameter change during pregnancy.[104] [5]

Management of type A aortic dissection (Figure 6)

As mortality due to aortic dissection remains high,[114] each symptomatic pregnant patient with known aortic disease or with signs or symptoms suspected of aortic dissection should be immediately evaluated in order to rule out aortic dissection. Echocardiography should be done promptly, if needed followed by computed tomography. Although MRI is preferred to avoid radiation exposure of the fetus, CT is performed much faster in the acute situation of a suspected aortic dissection and may be the method of choice in the acute setting. If aortic dissection is diagnosed, a patient should be treated similar as advised outside pregnancy. An extensive outline of management of aortic dissection has been reported in 2014.[115] The number of recommendations about aortic dissection during pregnancy is limited, probably due to lack of evidence. Type A aortic dissection warrants emergency aortic surgery. Whether this should be performed before, together with or after delivery depends on the viability of the fetus and the local situation (**Figure 6**).[116] A high

intraoperative fetal mortality rate has been reported in many case reports and series, indicating that delivery before surgery in case of a viable fetus is preferable.[5]

Management of type B aortic dissection (Figure 6)

The guidelines recommend conservative management in type B aortic dissections. Strict blood pressure regulation is warranted, with bedrest up to delivery. Fetal demise is reported to be as high as 35%, probably due to compromised uterine and placental perfusion.[117, 118] Frequent monitoring of the aortic status by MRI should be done during follow-up.

An alternative approach in complicated dissections of the descending aorta is an endovascular procedure (TEVAR). A few studies have reported favourable outcomes, some in acute type B aortic dissection.[119] Recently, a successful result with an endograft during pregnancy as bridge to open repair was presented.[120] More studies are warranted to determine further the safety and efficacy of this approach in pregnant women.

Although the role of beta-blockers in prevention of aortic dissection is equivocal, the benefit of use in patients with aortic dissection is clearer. In the IRAD study, beta-blockers were associated with better survival mainly after type A aortic dissections.[121] First choice are labetalol or metoprolol. Labetalol combines alpha and beta blocking properties and as such also reduces vascular resistance. During pregnancy, beta-blockers can be administered safely, with close monitoring of the fetus, as it may result in a lower birth weight.[122] Angiotensin receptor blockers and ACE inhibitors are contraindicated because of reported toxic effects on the fetal kidneys and bone malformations.[123] Hydralazine might be used instead, or on top of beta-blockers. However one should be cautious as hydralazine can induce brisk arterial relaxation with uteroplacental hypoperfusion. [125] Calcium channel inhibitors seem to exacerbate aneurysm growth, in a mouse model outside pregnancy,[124] and are therefore not first choice. Methyldopa, being first choice of treatment for gestational hypertension, might be administered as well, although there is little to no evidence on its use in women with aortic dissection.

Mechanical valve thrombosis

Incidence

Pregnancy is a hypercoagulable state, with decrease of anticoagulants such as protein S, and increase of coagulation factors and level of fibrinogen.[126, 127] The risk of mechanical valve thrombosis is obviously increased, and can lead to a catastrophic outcome of both mother and child. Several studies reported on the incidence of valve thrombosis, varying from 3.7% to 9.4%.[128-134] At high

risk are women with a mechanical valve in mitral or tricuspid position, or low flow due to ventricular dysfunction.[135] Also, sub therapeutic treatment poses a patient to an increased risk.[136] Therefore, switching anticoagulant agents in the first trimester and peripartum period is presumably associated with a high-risk. This is however, difficult to confirm, because of the limited number of studies with low numbers of events.

Diagnostics and Management (Figure 7)

In every pregnant patient with a mechanical valve prosthesis who presents with complaints of dyspnea, fatigue, palpitations, signs of heart failure, soft or absent prosthetic valve sounds or a systemic emboli, valve thrombosis should be suspected and ruled out.[136, 137] A transthoracic echocardiography is the first step towards diagnosis. If the diagnosis cannot be confirmed, and/or the patient is haemodynamically stable, a transoesophageal echocardiography (TOE) provides images at higher resolution with better views on the atrial edge and the ability to accurately determine the thrombus size, which is predictive of embolic risk.[138] If the diagnosis is still not clear, fluoroscopy might provide more insight with little radiation exposure to the fetus.[90, 136]

In haemodynamically unstable patients and obstructive thrombosis, emergency surgery is first choice treatment, preceded by caesarean section if the fetus is viable.[139] In case of a haemodynamically stable woman, different strategies are available, broadly in line with the approach of non-pregnant patients. Oral anticoagulant therapy or heparin may be continued and optimised in patients with a recent sub therapeutic INR, APTT or anti-Xa level, and non-obstructive left sided valve thrombosis.[5, 140] In other patients thrombolysis or surgery should be discussed and weighed. Outside pregnancy, thrombolysis as first choice seems to be beneficial opposed to surgery.[141, 142] However, randomised controlled trials are not yet available,[140] and the suggested estimated sample size of future studies will be hard to achieve.[141]

Fibrinolytic therapy does not or limitedly cross the placenta, but experience during human pregnancy is insufficient, in particular in women with a mechanical valve. Main concern is that fibrinolysis may cause systemic emboli, and hence, it should be avoided in patients with large and mobile thrombi, a left atrial thrombus as determined by TOE,[137, 143] or with a recent systemic emboli. Outside pregnancy, thrombolysis has shown to be an effective therapy, with high success rate in selected patients.[144] In patients with a right-sided valve thrombosis or when surgery is not directly available in the severely ill patient, it is the first choice therapy.[139] One study reported 24 consecutive women (2004-2012) with valve thrombosis during pregnancy, treated with a specific thrombolysis protocol, and showed reassuring results.[137] Patients were treated with slow infusion of low dose tissue plasminogen activator (t-PA, 25 mg) in 6 hours, which was repeated up to 6 times, with a

maximum dose of 150mg. Treatment was given under guidance of serial TOE, which is also current practice outside pregnancy.[143, 145, 146] Complete thrombus lysis was reached in all and no maternal mortality was observed. Five early pregnancies resulted in miscarriage, 1 to 5 weeks after thrombolytic therapy. The results of this study are encouraging, but the authors also emphasise that these treatment options are complementary: high-risk patients or those with a contraindication to or failure of thrombolysis, should still be considered for surgical therapy. In addition, a delivery in a woman with recent thrombolysis is very unattractive.

Surgical valve replacement or thrombectomy is preferred in patients with obstructive thrombosis and those who are critically ill.[139] Also large and mobile thrombi may be considered for direct surgery.[147] However, surgery is associated with a high rate of fetal mortality and morbidity,[148] although outcomes seem to have improved over time.[149, 150] Fetal demise occurs often when surgery is performed prior to delivery, with reported fetal mortality rates of 20-30%,[149-151] which is why delivery of a viable fetus should be performed prior to surgery. During surgery, physiological changes of pregnancy are accompanied by haemodilution, changes in coagulation and hypotension induced by cardiopulmonary bypass. Uteroplacental hypoperfusion is the reason for the high rate of fetal demise.[152] It has been suggested that normothermic surgery might bear lower risks than hypothermia.[153] Surgery should be performed in left lateral position and a higher pump flow is desired to maintain placental perfusion.

Summary

A multidisciplinary high-risk team should evaluate women suffering from cardiovascular emergencies, or those at high risk. Acute cardiovascular complications are potentially devastating events if not recognised early and treated by experienced specialists. Decisions concerning intervention and a delivery plan need to be made on an individual basis and often do not differ much from treatment outside pregnancy. Large studies investigating cardiac treatment for emergencies in pregnant women are lacking, and hence, therapeutic strategies are mainly based on expert opinion and small observational studies. Risks and benefits for both mother and child need to be outweighed, with a clear preference of at least maintaining a maternal haemodynamically stable situation.

Key points

- Treating pregnant women for a cardiac event means that there are two lives to save. Generally, a patient should get the same approach as a non-pregnant patient. If the fetus is viable, an urgent delivery is preferred, if safer for the mother, which expands further treatment options of the mother and reduces the cardiac burden.

- Heart failure is the most common complication during pregnancy; strong independent predictors before pregnancy are a diagnosis of cardiomyopathy and a WHO class 3 or 4. Signs of heart failure should be treated well before potential conception. Except for ACE inhibitors and angiotensin receptor blockers which are contraindicated, heart failure treatment is not different from outside pregnancy.
- The main aim of treating arrhythmias is to retrieve or maintain a haemodynamically stable situation. Immediate defibrillation is therefore indicated in any unstable patients. The majority of antiarrhythmic drugs should be considered as fetotoxic, but a lifethreatening maternal event does justify their use in the acute setting.
- In case of a maternal cardiac arrest with no success after four minutes, emergency caesarean section is indicated.
- Acute myocardial infarction is a potential catastrophic event and in case of a STEMI the first aim is to urgently reveal the underlying coronary anatomy, as this has therapeutic implications. A coronary dissection is the most common cause, which is a contraindication for thrombolysis.
- Acute aortic dissection should be treated following the guidelines of treatment in non-pregnant patient. In Type A dissection, an individualised decision should be made on whether the baby is delivered first by emergency caesarean section before aortic surgery is done.
- When a mechanical valve thrombosis during pregnancy has been diagnosed, thrombolysis may be considered in the same patients that would be a candidate outside pregnancy: in patients with right-sided prosthesis, patients who recently had subtherapeutic anticoagulation and non-critical ill patients. Emergency surgical replacement, preferably directly after caesarean section, is preserved for left-sided lesions and severely symptomatic patients.

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Tables

Table 1 Resuscitation in pregnant women

Figure legends:

Figure 1 Cardiac output change and timing of heart failure during pregnancy, delivery and postpartum

Data extracted from:

Robson SC, Dunlop W, Boys RJ, Hunter S. Cardiac output during labour. *Br Med J (Clin Res Ed)* 1987; 295(6607):1169-1172.

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Figure 2 Management of pregnant patients with acute heart failure

Figure 3 Management of supraventricular tachycardia during pregnancy

Figure 4 Management of ventricular tachycardia during pregnancy

Figure 5 Management of acute myocardial infarction during pregnancy

Figure 6 Management of acute aortic dissection during pregnancy

Figure 7 Management of mechanical valve thrombosis during pregnancy