BRITISH JOURNAL OF HOSPITAL MEDICINE

REVIEW

Maternal collapse in pregnancy

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Abstract

Maternal collapse is a rare life-threatening event that can occur at any stage of pregnancy or up to 6 weeks postpartum. Prompt identification and timely intervention by a multidisciplinary team that includes an obstetrician, midwifery staff and an obstetric anaesthetist are essential to improve maternal and fetal outcomes. Standard adult resuscitation guidelines need to be followed with some modifications, taking into account the maternal–fetal physiology, which clinicians should be familiar with. During cardiac arrest, the emphasis is on advanced airway management, manual uterine displacement to relieve aortocaval compression and performing a resuscitative hysterotomy (peri-mortem caesarean delivery) swiftly in patients who are more than 20 weeks gestation to improve maternal survival. Annual multidisciplinary simulation training is recommended for all professionals involved in maternity care; this can improve teamwork, communication and emergency preparedness during maternal collapse.

Key words: Aortic dissection; Cardiac arrest; Haemorrhage; Pregnancy; Pulmonary embolism; Resuscitation

Submitted: 30 May 2022; accepted following double-blind peer review: 3 October 2022

Introduction

Maternal collapse is defined as an acute event, caused by cardiovascular, respiratory or central nervous system failure occurring at any stage during pregnancy and up to 6 weeks postpartum, resulting in an absent or reduced conscious level (Chu et al, 2020). Untreated, it may lead to a maternal cardiac arrest or even death. The Royal College of Obstetricians and Gynaecologists has published evidence-based guidance on maternal collapse (Chu et al, 2020). As accurate rates of maternal collapse are unknown, severe maternal morbidity, cardiac arrest in pregnancy or maternal death rates are used to define its incidence.

A severe maternal morbidity rate of 635 per 100 000 births was reported in an Irish study (Manning et al, 2017), while a Scottish severe maternal morbidity report highlighted a rate of 730 per 100 000 births (Healthcare Improvement Scotland, 2014). A maternal cardiac arrest rate of 1 per 16 000 maternities was described in the cardiac arrest in pregnancy study (CAPS) with a maternal survival rate of 58% (Beckett et al, 2017). In the *Mothers and babies: reducing risk through audits and confidential enquiries across the UK* (MBRRACE-UK) report published in 2021, a maternal death rate of 8.8 per 100 000 women was recorded (Knight et al, 2021a). The MBRRACE-UK reports have highlighted significant racial and ethnic disparities with regards to maternal morbidity and mortality, with pregnant patients from ethnic minorities experiencing 2–4-fold higher rates of pregnancy-related deaths than white patients.

This article provides an overview of the common causes of maternal collapse along with the key messages highlighted in the MBRRACE reports while dealing with maternal collapse. Management of maternal cardiac arrest is discussed and the importance of debrief and the role of simulation in improving emergency preparedness of maternal collapse is also described.

How to cite this article:
Knapp C, Bhatia K. Maternal collapse in pregnancy. Br J Hosp Med. 2022. https://doi.org/10.12968/hmed.2022.0259

Anatomical and physiological changes of pregnancy

Healthcare professionals involved in resuscitating pregnant patients need to be aware of the implications of the systemic changes observed in pregnancy, the presence of the fetus, and pregnancy-specific pathology (eg pre-eclampsia, haemorrhage, peripartum cardiomyopathy) (Table 1).

Table 1. Anatomical and physiological changes of pregnancy and their implications for healthcare providers dealing with maternal collapse

System	Physiological changes of pregnancy	Implications
A: airway	Weight gain, enlarged breasts	Difficult intubation or ventilation
	Lower gastro-oesophageal tone	Increased pulmonary aspiration risk
	Delayed gastric emptying	Antacid prophylaxis necessary
	Laryngeal oedema (lower colloid osmotic pressure and vascular engorgement)	Epistaxis risk with nasopharyngeal airway
B: breathing	Increase respiratory rate	Respiratory rate >25/minute at rest is abnormal
	Decrease in functional residual capacity	Lower arterial partial pressure of CO_2 (pCO_2) (<4 kpA) with mild acidosis on blood gas. pCO_2 >4.5 kpA may be abnormal
	Diaphragmatic splinting	
	Increase oxygen demand	Lower oxygen reserve
	Fetus extracts 25% of maternal oxygen	Prone to develop hypoxia quickly
C: circulation	Increased heart rate or cardiac output	Left lateral tilt decreases aortocaval compression
	Peripheral vasodilatation	Increased cardiopulmonary circulation demand
	Decrease in systemic vascular resistance	Manual uterine displacement during cardiac arrest
	Aortocaval compression from the gravid uterus decreases preload	Intravenous access above diaphragm necessary
		Heart rate >120/minute is abnormal
	Physiological anaemia (greater increase in plasma volume compared to red cell mass)	Any new-onset cardiac symptoms, such as chest pain, back pain, pain needing opioid medications, dyspnoea on exertion, palpitations or syncope, needs investigations
	Decreased amount of mucopolysaccharides	
	Uterus receives 10% of maternal cardiac output at term	Risk of aortic dissection
		Pregnant patients can tolerate up to 30–35% circulating blood loss but then decompensate swiftly during haemorrhage
C: coagulation	Hypercoagulable state	Thromboembolic complications are common
	Increased levels of coagulation factors VIII, IX, X and fibrinogen, and decrease in fibrinolytic activity	
C: comorbidities	Raised body mass index, pre-eclampsia, diabetes, heart disease, mental health disorders and age >35 years at time of pregnancy	Heart disease, neurological disorders and maternal suicide are leading causes of maternal mortality
O: others	Systemic immunological adaptation	Sepsis is common

Use of early warning scores to identify maternal collapse

To help with early recognition and intervention in an unwell patient before maternal collapse, the MBRRACE reports recommended using the modified obstetric early warning scoring (MOEWS) system (Lewis et al, 2007), taking into account the physiological changes of pregnancy. These incorporate measurement of vital parameters like heart rate, blood pressure (systolic and diastolic), respiratory rate, oxygen saturation, temperature, pain, need for oxygen, and assessment of level of consciousness. Abnormal parameters trigger a colour-coded or a weighted-score system that guides the frequency of monitoring and urgency of review by specialists. The National Early Warning Score 2 endorsed by NHS England in adults is only recommended for use in patients <20 weeks' gestation (Chu et al, 2020).

These scoring systems provide a visual aid of individual physiology, can predict critical care admission and maternal morbidity and have high negative predictive values. A lack of a single universal validated MOEWS, variation in scoring, differing escalation protocols, parameters not recognising the physiological adaptations across different trimesters of pregnancy, staff shortages, staff training and the limited usefulness

of MOEWS in those with low-risk pregnancies are factors that undermine confidence in the validity of MOEWS for predicting maternal collapse (Robbins et al, 2019). An updated universal MOEWS score system is due to be released soon in the UK. Clinicians need to be aware that maternal collapse may occur without warning and with a normal MOEWS. Clinical judgement should be incorporated, especially in patients who look unwell or have specific risk factors.

Causes and initial management of maternal collapse

Maternal collapse may result from obstetric complications and/or from interventions undertaken during pregnancy (direct causes include haemorrhage, pre-eclampsia, anaesthesia) or from pre-existing disease, disease that develops during pregnancy or disease that is aggravated during pregnancy (indirect causes, eg asthma, heart disease) or may be coincidental (eg trauma). Resuscitation Council UK uses 4Hs and 4Ts (obstetric specific) in their guidelines (Table 2) to remember the possible causes (Resuscitation Council UK and Obstetric Anaesthetists' Association, 2021).

An obstetrician, an obstetric anaesthetist, a midwife, a neonatologist (if maternal gestational age is >22 weeks) and an intensivist should be involved promptly when an unwell pregnant patient presents to hospital. A systematic ABCDE approach should be undertaken by the multidisciplinary team to identify the cause. A left lateral tilt from head to toe at an angle of 15–30° on a firm surface will relieve aortocaval compression in the majority of pregnant patients.

In view of the lower oxygen reserve in pregnancy, high-flow oxygen should be provided during maternal collapse. Two 16-gauge intravenous cannulae should be inserted above the level of the diaphragm. If peripheral intravenous access is difficult, a central venous catheter or an intraosseous access (in the upper limb) should be considered. Appropriate bloods including a blood gas should be obtained, and fluid resuscitation commenced, although caution is needed with regards to fluid replacement in patients with pre-eclampsia and known heart disease. An alert, verbal stimulus, pain stimulus, unresponsive assessment along with pupillary examination should be performed along with exposure and examination, to aid assessment. Fetal wellbeing needs to be evaluated following maternal review. Common causes such as vasovagal collapse and hypoglycaemia should be ruled out. Emphasis should be placed on establishing a diagnosis rather than just ruling out a specific cause. Common causes with some key aspects of their management are described below.

Major haemorrhage

Major haemorrhage (>1000 ml) remains one of the leading causes of maternal collapse. The MBRRACE-UK report highlighted 14 deaths from haemorrhage (Knight et al, 2020). In early pregnancy, miscarriage or ruptured ectopic pregnancy are seen most often, while across the second and third trimesters, placenta praevia, placenta accreta, placental abruption and uterine rupture are common. Postnatally, uterine atony, retained products of conception and perineal trauma contribute to haemorrhage. Concealed haemorrhage, such as post caesarean birth, and less commonly from splenic artery or hepatic rupture, should be considered in the collapsed patient.

A multidisciplinary approach is required to manage ongoing haemorrhage, involving the senior obstetrician, anaesthesia, midwifery and haematology staff. Specific management consists of seeking senior support early along with activation of a massive obstetric haemorrhage call, aggressive fluid resuscitation, targeted transfusion of blood products aiming for a normal coagulation profile, fibrinogen >2 g/litre, platelets >75x10^9/litre and haemoglobin >80 g/litre, avoiding hypothermia, administration of uterotonics, tranexamic acid and vasopressors. Invasive monitoring of blood pressure, along with cardiac output monitoring, can be used to guide maternal resuscitation. The MBRRACE-UK report (Knight et al, 2020) recommends that the response to obstetric haemorrhage is tailored to the proportionate blood loss as a percentage of circulating blood volume based on a woman's body weight. Point-of-care testing of haematological parameters (haemoglobin), coagulation parameters (thromboelastography, thromboelastometry) and biochemical parameters (lactate, base deficit) are useful for monitoring of the effectiveness of resuscitation.

Table 2. Common obstetric-specific causes of obstetric cardiac arrest

4Hs		4Ts	
Hypoxia	■ Pulmonary embolus ■ Failed intubation or aspiration ■ Heart failure – peripartum cardiomyopathy, myocardial infarction, aortic dissection ■ Anaphylaxis ■ Eclampsia or pre-eclampsia – pulmonary oedema, seizure ■ Intracranial haemorrhage ■ Pneumonia (caused by COVID-19)	Thrombosis	■ Amniotic fluid embolus ■ Air embolus ■ Pulmonary embolism ■ Myocardial infarction
Hypovolaemia	■ Haemorrhage – massive obstetric haemorrhage, splenic or hepatic artery rupture, aneurysm rupture ■ Sepsis ■ Anaphylaxis ■ High regional anaesthesia	Toxins	■ Local anaesthetic systemic toxicity ■ Opioids (eg remifentanil patient-controlled analgesia for labour) ■ Illicit drugs ■ Self-harm ■ Magnesium ■ Tranexamic acid
Hypothermia		Tamponade	■ Trauma ■ Aortic dissection
Hypo- or hyperkalaemia (and electrolytes)	■ Hyponatremia – by oxytocin use ■ Hypokalaemia/hypomagnesemia – severe hyperemesis gravidarum ■ Hyperkalaemia – renal failure ■ Hypermagnesaemia ■ Hypoglycaemia	Tension pneumothorax	■ Trauma ■ Use of 50:50 mix of oxygen:nitrous oxide

modified from Resuscitation Council UK and Obstetric Anaesthetists' Association (2021)

Obstetric surgical management includes a laparotomy, caesarean birth, use of a Bakri balloon, uterine packing, uterine compression sutures, uterine artery embolisation and hysterectomy (Mavrides et al, 2016). One senior clinician should take an overview (a 'helicopter view') of ongoing resuscitation, taking into account all the information available, so as to direct and coordinate appropriate care during haemorrhage (Knight et al, 2020).

Thromboembolism

Venous thromboembolism remains the leading cause of direct maternal deaths, with 32 deaths reported in the 2021 report, mainly from pulmonary embolism and cerebral venous sinus thrombosis (Knight et al, 2021a). Classic symptoms of chest pain, groin pain, leg swelling, along with dyspnoea or haemoptysis, especially in high-risk patients (eg raised body mass index, previous venous thromboembolism), may point to the diagnosis of pulmonary embolism. Chest X-ray, electrocardiogram, computed tomography pulmonary angiogram (if X-ray chest is abnormal) and ventilation–perfusion scans may be used to confirm the diagnosis.

Low-molecular weight heparin is the anticoagulant of choice for prophylaxis of venous thromboembolism and acute pulmonary embolism in pregnancy and is preferred over unfractionated heparin because of its superior bioavailability, lower side effects, lower maternal mortality and lower recurrence rates of venous thromboembolism (Royal College of Obstetricians and Gynaecologists, 2015). Therapeutic anticoagulation with unfractionated heparin, including a weight-adjusted bolus intravenous injection, can be initiated in patients with high-risk pulmonary embolism (Konstantinides et al, 2020). It has a short half-life and is readily reversible. Its disadvantages include the need for frequent measurement of activated partial thromboplastin time and titrating the activated partial thromboplastin time ratio to 1.5–2.5 times the average laboratory control value. Systemic thrombolysis (using intravenous alteplase 50–100 mg) should be administered as per Royal College

of Obstetricians and Gynaecologists (2015) recommendations in patients with massive pulmonary embolism and haemodynamic compromise or those with limb- or life-threatening complications from extensive iliofemoral vein thrombosis.

Recommendations from the MBRRACE 2021 report emphasise the importance of pre-pregnancy counselling in patients with previous venous thromboembolism. All patients should undergo a documented assessment of risk factors using the Royal College of Obstetricians and Gynaecologists (2015) venous thromboembolism risk assessment score pre-pregnancy and during the peripartum period. A dynamic venous thromboembolism risk assessment throughout pregnancy, including re-weighing the patient at 28 weeks, and appropriate dosing of low-molecular weight heparin for prophylaxis was also recommended. Patient adherence to administration of low-molecular weight heparin should be part of the antenatal and postnatal assessment in high-risk patients. Developing clear structured haematology care plans is essential for patients receiving prophylactic and therapeutic anticoagulation, during the antepartum, intrapartum and postpartum period (Knight et al, 2021a).

Amniotic fluid embolism

This is a rare, catastrophic condition (2 in 100 000 maternities) that may occur during induction of labour, or during caesarean birth in absence of clear cause. It is characterised by sudden-onset hypoxia, pulmonary oedema, hypotension, fetal compromise and maternal collapse followed by coagulopathy and neurological signs and symptoms. A maternal mortality rate of 20% has been reported (Tuffnell et al, 2011). Eight maternal deaths from amniotic fluid embolism were reported in the MBRRACE 2020 report, all following induction of labour. Patients may need prompt delivery, cardiopulmonary resuscitation, fluid replacement and treatment for disseminated intravascular coagulation. Transthoracic echocardiography may be useful in elucidating the aetiology of maternal shock (Simard et al, 2021).

Sepsis

Sepsis contributed to 23 maternal deaths during the 2016–18 triennia (Knight et al, 2020). Genitourinary tract infection and pneumonia were the main sources. Sepsis and septic shock during pregnancy should be managed in line with Surviving Sepsis guidelines (Evans et al, 2021). Early antibiotic administration, fluid resuscitation, vasopressors with appropriate invasive and/or cardiac output monitoring along with critical care input are recommended in the presence of organ dysfunction.

Cardiorespiratory and thrombotic complications from COVID-19 contributed to 33 maternal deaths between March 2020 and September 2021 (Knight et al, 2021b). Pregnant patients from ethnic minorities, age >35 years, unvaccinated or those with comorbidities including raised body mass index, hypertensive disorders of pregnancy, diabetes and asthma are at increased risk of hospitalisation and complications from COVID-19. Symptomatic pregnant patients with COVID-19 were more likely to require critical care admission (Bhatia et al, 2022). Any pregnant unwell patient with COVID-19 needs dedicated input from a multidisciplinary team familiar with the escalation and treatment pathways. Treatment should be as for any non-pregnant symptomatic patient and comprises low-molecular weight heparin prophylaxis, oxygen to maintain oxygen saturations above 94%, steroids if oxygen dependent, tocilizumab if C-reactive protein levels are >75 mg/litre, or if in critical care, and monoclonal antibodies if indicated. Vaccination is safe and strongly protective against severe disease (Knight et al, 2021b). Ensuring pregnant people have unrestricted access to COVID-19 vaccination should be a priority in every country worldwide (Kalafat et al, 2022).

Cardiac disease

Heart disease is the leading cause of maternal mortality in the UK. Cardiomyopathy, myocardial ischaemia, cardiac arrhythmias, sudden cardiac deaths and aortic dissection contributed to the majority of deaths (Knight et al, 2019). Appropriate pre-conception counselling, risk assessment, identifying red flag symptoms, early referral of high-risk patients to a tertiary centre, involvement of a multidisciplinary cardio-obstetrics team, investigating any new-onset cardiac symptoms with an echocardiogram, use of biomarkers (troponins and N-terminal pro-B-type natriuretic peptide) and development of individualised peripartum cardiac care plans are some recommendations, in line with European Society

of Cardiology guidelines to decrease morbidity and mortality in patients with heart disease (Regitz-Zagrosek et al, 2018). Pregnant patients with cardiac comorbidities, needing invasive cardiac interventions or cardioversion should be treated similarly to non-pregnant patients in line with resuscitation guidelines. Life-saving emergency medications should not be withheld just because an individual is pregnant.

Pre-eclampsia

Pre-eclampsia and eclampsia contributed to four maternal deaths in the 2020 MBRRACE report. Seizure activity after 20 weeks' gestation should be considered to be eclampsia unless proven otherwise, especially in a patient not known to have a history of epilepsy (Royal College of Obstetricians and Gynaecologists, 2016). Targeted blood pressure management using antihypertensives aiming for a blood pressure <135/85 mmHg, intravenous magnesium sulphate for seizure prophylaxis, cautious fluid administration, aspirin and timely delivery remain key management strategies for pre-eclampsia (McGarey et al, 2022). Clinicians need to be familiar with the National Institute for Health and Care Excellence (2019) guidelines on management of hypertension in pregnancy.

Neurological disease

Neurological conditions were the second most common cause of indirect maternal death, with epilepsy and stroke contributing to the majority of maternal deaths. Headache is one of the most common manifestations of intracranial pathology, especially pre-eclampsia, cerebral venous sinus thrombosis or intracranial haemorrhage. Neurological examination including fundoscopy is mandatory in all women with a new-onset headache or a headache with atypical symptoms (Knight et al, 2020).

Intracranial haemorrhage, vascular malformations, cerebral venous sinus thrombosis or cerebral ischaemia may cause stroke in pregnancy (30 per 100 000 maternities). The majority occur in the peripartum period or in the 6 weeks following delivery (Swartz et al, 2017). The emphasis is on early involvement of neurologists and neurosurgeons, neuroimaging, maintenance of blood pressure and strategies to decrease intracranial pressure. Pregnancy should not alter the standard of care for stroke (Knight et al, 2020). The MBRRACE 2020 report emphasised the need to develop specific pathways to ensure pregnant patients with stroke receive the rapid specialist care they need.

Twenty-two maternal deaths were reported from causes related to epilepsy during or up to a year after the end of pregnancy in the 2016–18 triennia. Sudden unexpected death in epilepsy was recorded in 18 patients. Tonic-clonic seizures, uncontrolled seizures, nocturnal seizures, diagnosis of epilepsy before the age of 16 years and ineffective antiepileptic treatment are some of the risk factors contributing to an increase in sudden unexpected death in epilepsy (Knight et al, 2020). Patients with epilepsy should have pre-conception counselling and, when pregnant, be assessed for risk factors for seizures and have regular planned antenatal care with a dedicated epilepsy team (Royal College of Obstetricians and Gynaecologists, 2016).

Anaphylaxis

Anaphylaxis has an incidence of 1.5 per 100 000 maternities (McCall et al, 2020) and is commonly caused by antibiotics and muscle relaxants administered (as part of a general anaesthetic) during pregnancy. Caesarean birth, previous history of an allergic reaction and Black ethnicity seem to be key risk factors (McCall et al, 2019). In severe maternal shock, the presence of a pulse may be an unreliable indicator of adequate cardiac output. In the absence of a recordable blood pressure or other indicator of cardiac output, early initiation of external cardiac compressions may be life-saving (Knight et al, 2020). Adrenaline remains the mainstay of treatment (Soar et al, 2021).

Anaesthesia

Complications of anaesthesia caused almost 25% of cardiac arrest cases in the CAPS study, but all affected patients survived (Beckett et al, 2017). Total or high spinal, failed intubation, anaphylaxis, respiratory depression from opioid use and local anaesthetic systemic toxicity contribute to maternal collapse following anaesthesia. Management should focus on ABCDE assessment with identification and treatment of causality. Checklists can

be useful to guide treatment. Intralipid is recommended for treatment of local anaesthetic systemic toxicity (Association of Anaesthetists, 2010).

Trauma

Trauma remains one of the leading causes of non-obstetric maternal death. Motor vehicle accident, domestic violence, blunt or penetrating injuries and falls contribute to injuries. A structured approach should be followed, and resuscitation managed in line with trauma life support guidance. Good communication with trauma team members, along with the anaesthetist, obstetrician and neonatology team, is vital. Placental abruption, uterine rupture and preterm labour need to be considered, along with fetal monitoring. A focused assessment sonography in trauma or point-of-care ultrasound by experienced personnel is recommended to rule out haemoperitoneum. Laparotomy should not be delayed if the point-of-care ultrasound findings are negative and/or the index of suspicion is high (Chu et al, 2020). Computed tomography scanning should not be denied to a pregnant individual, as the risks of radiation in pregnancy are small compared with the risk of missed or delayed diagnosis of significant maternal injury. Anaesthetic non-technical skills including task management, team working, situation awareness and decision making are all critical determinants of successful trauma resuscitation (Flin et al, 2010).

Substance misuse and medication errors

Four maternal deaths were directly attributed to primary substance abuse (alcohol or drug abuse) in the MBRRACE-UK 2021 report (Knight et al, 2021a). Medications used during labour, such as magnesium sulphate, local anaesthetics, insulin or opiates, can also cause adverse effects. Medication errors may also contribute to maternal collapse, with a detailed review reporting 10 maternal deaths following accidental intrathecal administration of tranexamic acid (Patel et al, 2019).

Maternal cardiac arrest

Progression to cardiac arrest remains a risk until the cause of the collapse is addressed. Communication is crucial, and it is important to declare an ‘obstetric cardiac arrest’ by calling 2222 if in-hospital or 999 if in the community in the UK. In the community, basic life support should be provided, and rapid transfer to hospital arranged.

Figure 1 shows a quick reference guide from the Resuscitation Council UK, MBRRACE and the Obstetric Anaesthetists’ Association that summarises the causes and key elements of management during an in-hospital obstetric cardiac arrest. One member of the team should be assigned the task of recording interventions, fluids, medications, blood and components transfused, and vital signs during maternal collapse or cardiac arrest (Knight et al, 2020). Key aspects of resuscitation in a maternal cardiac arrest are specified below:

Airway and breathing (A, B)

During cardiac arrest, insertion of a supraglottic airway with a gastric port or early endotracheal intubation by an experienced anaesthetist is advisable to decrease the risk of aspiration. Failed intubation is more common in pregnant than non-pregnant patients and there should always be a plan for failed intubation (Mushambi et al, 2015). Smaller sized endotracheal tubes (sizes 7.0 or lower) should be available. Videolaryngoscopy is recommended to increase first pass tracheal intubation success. Waveform capnography should be used to confirm tracheal tube placement. It also serves as an aid to assess the quality of cardiopulmonary resuscitation and to provide an early indication of a return of spontaneous circulation (Chu et al, 2020). Once the airway is secured, ventilation should be at 10–12 breaths per minute as per the Resuscitation Council UK life support algorithm (Soar et al, 2021).

Circulation, chest compressions, aortocaval compression and cervical spine protection (C)

Two large bore intravenous access above the diaphragm are recommended in view of uterine compression and bleeding below the diaphragm. Alternatively, a proximal humeral intraosseous access may be necessary. A 15–30° head-to-toe lateral tilt on a firm surface is needed, as described above. At maternal gestational age >20 weeks (assumed if the

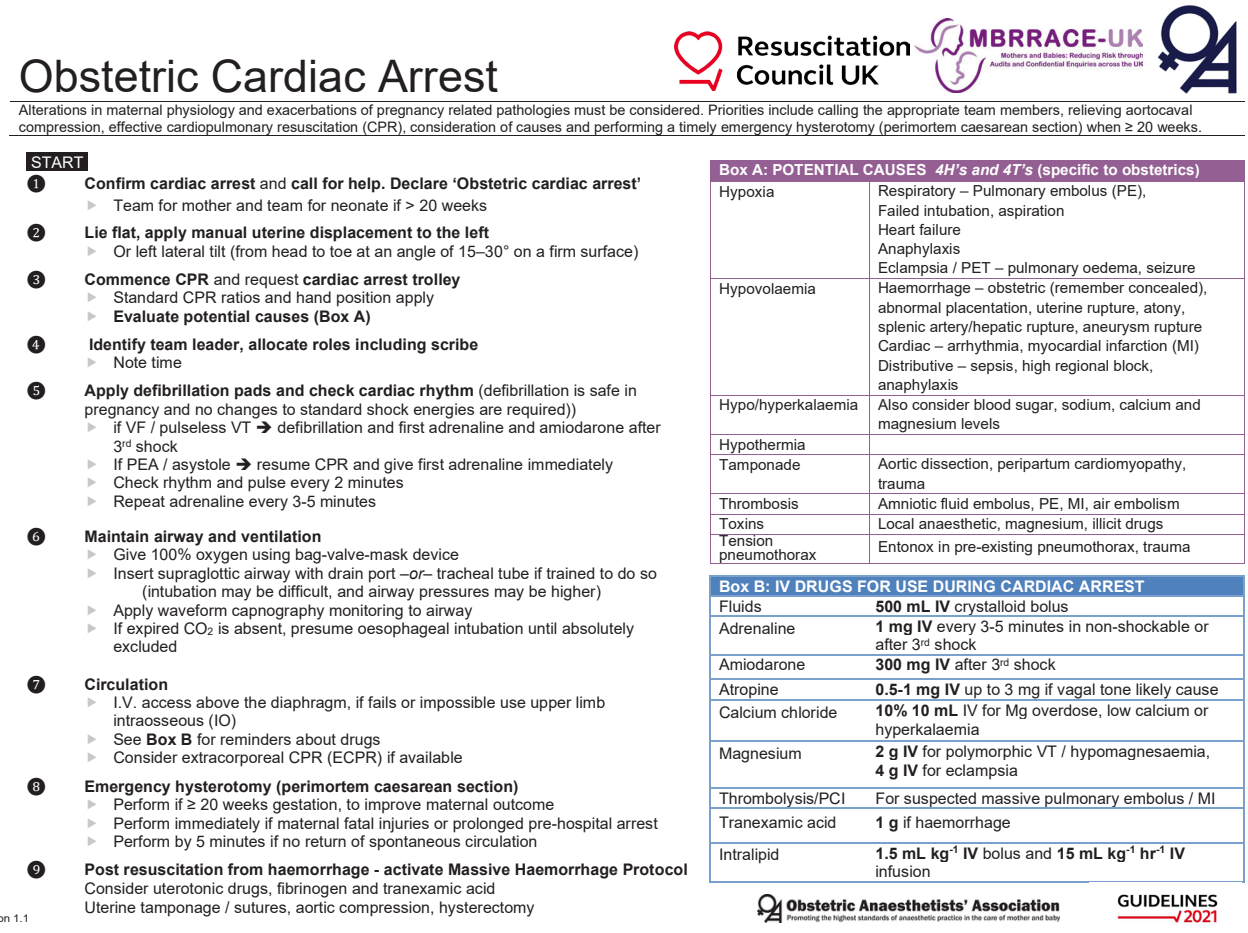
fundus reaches or exceeds the level of the umbilicus), manual displacement of the uterus is recommended during arrest as it aids venous return. In cases of major trauma, the spine should be protected with a spinal board before any tilt is applied or manual displacement of the uterus is recommended. Uninterrupted chest compressions should be performed at a rate of 100–120/minute. Point-of-care ultrasound including transthoracic echocardiography is useful in diagnosis and management of cardiac tamponade and pneumothorax, and its use continues to increase in emergency settings (Díaz-Gómez et al, 2021). Point-of-care ultrasound is also useful for revealing concealed haemorrhage or intraperitoneal fluid, but should not interfere with ongoing resuscitation.

Defibrillation and drugs (D)

Defibrillation should be performed for a shockable rhythm (pulseless ventricular tachycardia or ventricular fibrillation) with the same energy levels as for a non-pregnant patient. Adhesive pads can be placed in the standard position or along the anterior and posterior precordium if breasts hinder normal placement. Automated external defibrillation is safe for the fetus. Any ongoing drug infusions that may have a negative ionotropic effect (oxytocin, magnesium or local anaesthetic) should be stopped. There should be no alteration in the algorithm drugs or doses used in the Resuscitation Council UK protocols (Soar et al, 2021). Throughout the resuscitation process, consideration should be given to the cause of the collapse, so that ongoing therapy can be directed towards the specific cause to optimise outcome.

Exposure, examination and equipment (E)

Exposure for a brief examination should be undertaken to rule out bleeding, rash and in preparation for a resuscitative hysterotomy. A scalpel and umbilical cord clamps (or alternative ligatures) should be available on the resuscitation trolley in all areas where maternal collapse



Obstetric Cardiac Arrest

Resuscitation Council UK

MBRRACE-UK Mothers and Babies: Reducing Risk through Audits and Confidential Enquiries across the UK

Alterations in maternal physiology and exacerbations of pregnancy related pathologies must be considered. Priorities include calling the appropriate team members, relieving aortocaval compression, effective cardiopulmonary resuscitation (CPR), consideration of causes and performing a timely emergency hysterotomy (perimortem caesarean section) when ≥ 20 weeks.

START

1. **Confirm cardiac arrest** and **call for help. Declare 'Obstetric cardiac arrest'**
   - Team for mother and team for neonate if > 20 weeks
2. **Lie flat, apply manual uterine displacement to the left**
   - Or left lateral tilt (from head to toe at an angle of 15–30° on a firm surface)
3. **Commence CPR** and request **cardiac arrest trolley**
   - Standard CPR ratios and hand position apply
   - **Evaluate potential causes (Box A)**
4. **Identify team leader, allocate roles including scribe**
   - Note time
5. **Apply defibrillation pads and check cardiac rhythm** (defibrillation is safe in pregnancy and no changes to standard shock energies are required))
   - if VF / pulseless VT ➔ defibrillation and first adrenaline and amiodarone after 3rd shock
   - If PEA / asystole ➔ resume CPR and give first adrenaline immediately
   - Check rhythm and pulse every 2 minutes
   - Repeat adrenaline every 3-5 minutes
6. **Maintain airway and ventilation**
   - Give 100% oxygen using bag-valve-mask device
   - Insert supraglottic airway with drain port *–or–* tracheal tube if trained to do so (intubation may be difficult, and airway pressures may be higher)
   - Apply waveform capnography monitoring to airway
   - If expired CO_2 is absent, presume oesophageal intubation until absolutely excluded
7. **Circulation**
   - I.V. access above the diaphragm, if fails or impossible use upper limb intraosseous (IO)
   - See **Box B** for reminders about drugs
   - Consider extracorporeal CPR (ECPR) if available
8. **Emergency hysterotomy (perimortem caesarean section)**
   - Perform if ≥ 20 weeks gestation, to improve maternal outcome
   - Perform immediately if maternal fatal injuries or prolonged pre-hospital arrest
   - Perform by 5 minutes if no return of spontaneous circulation
9. **Post resuscitation from haemorrhage - activate Massive Haemorrhage Protocol**
   Consider uterotonic drugs, fibrinogen and tranexamic acid
   Uterine tamponage / sutures, aortic compression, hysterectomy

Version 1.1

Box A: POTENTIAL CAUSES *4H's and 4T's* (specific to obstetrics)

Hypoxia	Respiratory – Pulmonary embolus (PE), Failed intubation, aspiration Heart failure Anaphylaxis Eclampsia / PET – pulmonary oedema, seizure
Hypovolaemia	Haemorrhage – obstetric (remember concealed), abnormal placentation, uterine rupture, atony, splenic artery/hepatic rupture, aneurysm rupture Cardiac – arrhythmia, myocardial infarction (MI) Distributive – sepsis, high regional block, anaphylaxis
Hypo/hyperkalaemia	Also consider blood sugar, sodium, calcium and magnesium levels
Hypothermia	
Tamponade	Aortic dissection, peripartum cardiomyopathy, trauma
Thrombosis	Amniotic fluid embolus, PE, MI, air embolism
Toxins	Local anaesthetic, magnesium, illicit drugs
Tension pneumothorax	Entonox in pre-existing pneumothorax, trauma

Box B: IV DRUGS FOR USE DURING CARDIAC ARREST

Fluids	**500 mL IV** crystalloid bolus
Adrenaline	**1 mg IV** every 3-5 minutes in non-shockable or after 3rd shock
Amiodarone	**300 mg IV** after 3rd shock
Atropine	**0.5-1 mg IV** up to 3 mg if vagal tone likely cause
Calcium chloride	**10% 10 mL** IV for Mg overdose, low calcium or hyperkalaemia
Magnesium	**2 g IV** for polymorphic VT / hypomagnesaemia, **4 g IV** for eclampsia
Thrombolysis/PCI	For suspected massive pulmonary embolus / MI
Tranexamic acid	**1 g** if haemorrhage
Intralipid	**1.5 mL kg^{-1} IV** bolus and **15 mL kg^{-1} hr^{-1} IV** infusion

Obstetric Anaesthetists' Association
Promoting the highest standards of anaesthetic practice in the care of mother and baby

GUIDELINES 2021

Figure 1. Quick reference guide for management of an obstetric cardiac arrest. From Resuscitation Council UK and Obstetric Anaesthetists' Association (2021).

may occur, including accident and emergency units (Chu et al, 2020). Equipment for neonatal resuscitation should also be available and regularly checked (Soar et al, 2021).

Resuscitative hysterotomy and fetus (F)

In maternal cardiac arrest >20 weeks gestation, a resuscitative hysterotomy (peri-mortem caesarean delivery) should be performed if there is no return to spontaneous circulation after standard resuscitation within 4 minutes. Advantages include removal of the fetus, relief of aortocaval compression, ease of performing chest compressions and improvement in pulmonary ventilation dynamics. It also allows trans-diaphragmatic internal cardiac resuscitation. Maternal and neonatal survival rates are higher if the time from arrest to resuscitative hysterotomy is less than 5 minutes vs more than 5 minutes (61% vs 35% maternal and 96% v 70% neonatal). Higher maternal survival rates were reported when the hysterotomy took place at the point of collapse (72% vs 36%). Time should not be wasted moving the patient to theatre (Beckett et al, 2017).

A midline suprapubic or transverse incision may be undertaken for peri-mortem caesarean delivery. Although commonly performed by an obstetrician, rarely a non-obstetrician may need to perform this. A review of peri-mortem caesarean delivery performed on 94 patients identified that 54.3% (51/94) of mothers survived to hospital discharge, with 78.4% (40/51) surviving with a good to moderately impaired neurological outcome. Neonatal survival (nearly 60%) was strongly associated with in-hospital arrest (Einav et al, 2012).

Echocardiography and extracorporeal cardiopulmonary resuscitation

Although transthoracic echocardiography is more commonly used during maternal collapse, in specialised centres, transoesophageal echocardiogram can delineate the cause of arrest and assess the efficacy of resuscitation (Madden and Meng, 2020). Hypovolaemia, thromboembolism, tamponade, pleural or pericardial effusion and aortic dissection are some of the common differential diagnoses that can be quickly ruled out.

Extracorporeal membrane oxygenation has been used in critically ill obstetric patients in tertiary centres. When the cause of arrest has a cardiopulmonary cause, extracorporeal cardiopulmonary resuscitation (extracorporeal membrane oxygenation during cardiac arrest) can be considered (Naoum et al, 2020).

Post-resuscitation care

If resuscitation is successful following resuscitative hysterotomy, there should be prompt transfer to theatre and activation of the massive haemorrhage protocol should be considered. Following stabilisation, the patient will need to be transferred to critical care for appropriate post-resuscitation care (Nolan et al, 2021).

Human factors, governance, debrief and simulation

Good leadership, closed-loop communication and task allocation (including documentation for any medicolegal issues arising) are paramount. An incident form should be completed, and a review undertaken with the aim of improving systems and care provision. The coroner, MBRRACE-UK and more recently the Health Safety Investigation Board have to be informed in the event of a maternal death or an adverse fetal or neonatal outcome.

Maternal collapse can be associated with post-traumatic stress disorder, postnatal depression and tocophobia (severe fear of pregnancy and childbirth). Debriefing the patient along with the relatives is important for the mental wellbeing of all affected (Chu et al, 2020). Appropriate debrief for staff is crucial, as it may identify and potentially mitigate the negative impact of critical events on healthcare providers (Arriaga et al, 2020). Poor resuscitation skills and suboptimal care (in nearly 40%) leading to poor outcomes are often cited in MBRRACE reports. Annual multidisciplinary simulation drills focusing on specific obstetric emergencies and life support training is recommended by the Royal College of Obstetricians and Gynaecologists (Chu et al, 2020) and also is a requirement for NHS Resolution and the clinical negligence scheme for trusts in England and Wales. Simulation improves anaesthetic non-technical skills and technical skills, and is reported to reduce the time to initiate cardiopulmonary resuscitation and peri-mortem caesarean delivery (Fisher et al, 2011).

Key points

- Maternal collapse, although rare, may be caused by a wide range of pathologies.
- Timely multidisciplinary intervention in an unstable pregnant patient is essential to prevent cardiac arrest.
- Point-of-care ultrasound may aid early recognition of the cause of maternal collapse, guide decision making and direct treatment.
- During cardiac arrest, the emphasis is on effective cardiopulmonary resuscitation, manual uterine displacement, early intubation and resuscitative hysterotomy (peri-mortem caesarean delivery), along with early identification and treatment of the cause of maternal collapse.
- Extracorporeal membrane oxygenation can be considered in a critically ill patient or following maternal cardiac arrest in specialised centres.

Conclusions

Although a rare event, the consequences of a maternal collapse can be devastating for the mother and fetus. Outcomes often depend on the cause, location, access to emergency care and quality of resuscitation provided at the time of collapse. For peripartum healthcare providers, the emphasis should be on timely intervention to prevent maternal collapse progressing to a cardiac arrest. Good effective cardiopulmonary resuscitation, manual uterine displacement, early use of resuscitative hysterotomy and use of advanced techniques like extracorporeal membrane oxygenation can improve both maternal and fetal survival in a maternal cardiac arrest.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Acknowledgement

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