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Maternal Collapse in Pregnancy and the Puerperium

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Maternal Collapse in Pregnancy and the Puerperium

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This is the second edition of this guideline. The first edition was published in 2011 under the same title.

Executive summary

Clinical issues

Can women at risk of impending collapse be identified early?

An obstetric modified early warning score chart should be used for all women undergoing observation, to allow early recognition of the woman who is becoming critically ill. D

What are the causes of maternal collapse?

Maternal collapse can result from a number of causes. A systematic approach should be taken to identify the cause. ***[New 2019]*** B

In cases of collapse assumed to be due to anaphylaxis mast cell tryptase levels can be useful in confirming the diagnosis. ✓

What are the physiological and anatomical changes in pregnancy that affect resuscitation?

It is essential that anyone involved in the resuscitation of pregnant women is aware of the physiological differences. This includes pre-hospital care clinicians, paramedics and emergency medicine department staff. ✓

Aortocaval compression significantly reduces cardiac output from 20 weeks of gestation onwards and the efficacy of chest compressions during resuscitation. ***[New 2019]*** C

Changes in lung function, diaphragmatic splinting and increased oxygen consumption make pregnant women become hypoxic more readily and make ventilation more difficult. ***[New 2019]*** C

Difficult intubation is more likely in pregnancy. ***[New 2019]*** C

Pregnant women are at an increased risk of aspiration. ***[New 2019]*** C

What is the optimal initial management of maternal collapse?

Maternal collapse resuscitation should follow the Resuscitation Council (UK) guidelines using the standard ABCDE approach, with some modifications for maternal physiology, in particular relief of aortocaval compression. D

If maternal cardiac arrest occurs in the community setting, basic life support should be administered and rapid transfer arranged. ✓

Manual displacement of the uterus to the left is effective in relieving aortocaval compression in women above 20 weeks' gestation or where the uterus is palpable at or above the level of the umbilicus. This permits effective chest compressions in the supine position in the event of cardiac arrest. D

A left lateral tilt of the woman from head to toe at an angle of 15–30° on a firm surface will relieve aortocaval compression in the majority of pregnant women and still allow effective chest compressions to be performed in the event of cardiac arrest. C

In cases of major trauma, the spine should be protected with a spinal board before any tilt is applied. In the absence of a spinal board, manual displacement of the uterus should be used. ✓
[New 2019]

Intubation in an unconscious woman with a cuffed endotracheal tube should be performed immediately by an experienced anaesthetist. ✓

Supplemental high flow oxygen should be administered as soon as possible to counteract rapid deoxygenation. ✓

Bag and mask ventilation or insertion of a simple supraglottic airway should be undertaken until intubation can be achieved. ✓

If the airway is clear and there is no breathing, chest compressions should be commenced immediately. B

Two wide-bore cannulae (minimum 16 gauge) should be inserted as soon as possible. If peripheral venous access is not possible, early consideration of central venous access, intraosseous access or venous cutdown should be considered. ✓

There should be an aggressive approach to volume replacement, although caution should be exercised in the context of pre-eclampsia or eclampsia. ✓

Abdominal ultrasound by a skilled operator can assist in the diagnosis of concealed haemorrhage. C

The same defibrillation energy levels should be used as in a nonpregnant woman. B

There should be no alteration in algorithm drugs or doses used in the Resuscitation Council (UK) protocols. ✓

Common, reversible causes of maternal cardiopulmonary arrest should be considered throughout the resuscitation process. D

Resuscitation efforts should be continued until a decision is taken by the consultant obstetrician and consultant anaesthetist to discontinue resuscitation efforts. This decision should be made in consensus with the cardiac arrest team. ✓

When, where and how should perimortem caesarean section (PMCS) be performed?

In women over 20 weeks of gestation, if there is no response to correctly performed CPR within 4 minutes of maternal collapse or if resuscitation is continued beyond this, then PMCS should be undertaken to assist maternal resuscitation. Ideally, this should be achieved within 5 minutes of the collapse. D

PMCS should not be delayed by moving the woman. It should be performed where maternal collapse has occurred and resuscitation is taking place. ✓

The operator should use the incision, which will facilitate the most rapid access. This may be a midline vertical incision or a suprapubic transverse incision. ✓

A scalpel and umbilical cord clamps (or alternative ligatures) should be available on the resuscitation trolley in all areas where maternal collapse may occur, including the accident and emergency department. ✓

What does the ongoing management consist of?

Senior staff with appropriate experience should be involved at an early stage. ✓

Transfer should be supervised by an adequately skilled team with appropriate equipment. ✓

In the case of maternal collapse secondary to antepartum haemorrhage, the fetus and placenta should be delivered promptly to allow control of the haemorrhage. ✓

In the case of massive placental abruption, caesarean section may occasionally be indicated even if the fetus is dead to allow rapid control of the haemorrhage. ✓

Intravenous tranexamic acid significantly reduces mortality due to postpartum haemorrhage. ***[New 2019]*** A

Massive pulmonary embolism should be treated according to RCOG Green-top Guideline No. 37b *Acute Management of Thrombosis and Embolism during Pregnancy and the Puerperium*. *[New 2019]* D

The management of amniotic fluid embolism (AFE) is supportive rather than specific, as there is no proven effective therapy. ✓

Early involvement of senior experienced staff, including midwives, obstetricians, anaesthetists, haematologists and intensivists, is essential to optimise outcome. ✓

Coagulopathy needs early, aggressive treatment, including the use of fresh frozen plasma. ✓

Recombinant factor VII should only be used if coagulopathy cannot be corrected by massive blood component replacement as it causes poorer outcome in women with AFE. *[New 2019]* C

After successful resuscitation, cardiac cases should be managed by an expert cardiology team. ✓

Septic shock should be managed in accordance with the Surviving Sepsis Campaign guidelines. D

The antidote to magnesium toxicity is 10 ml 10% calcium gluconate or 10 ml 10% calcium chloride given by slow intravenous injection. ✓

If local anaesthetic toxicity is suspected, stop injecting immediately. ✓

Lipid rescue should be used in cases of collapse secondary to local anaesthetic toxicity. C

Intralipid® 20% should be available in all hospitals offering maternity services. ✓

Manage arrhythmias as usual, recognising that they may be very refractory to treatment. ✓

All cases of lipid rescue should be reported to NHS Improvement and the Lipid Rescue site. ✓

Eclampsia should be managed in accordance with the NICE Clinical Guideline 107 *Hypertension in Pregnancy: Diagnosis and Management*. *[New 2019]* D

Neuroradiologists and neurosurgeons should be involved in the care of pregnant women with intracranial haemorrhage at the earliest opportunity. *[New 2019]* ✓

In cases of anaphylaxis, all potential causative agents should be removed, and the ABCDE approach to assessment and resuscitation followed. ✓

If the anaphylactic reaction occurs in the community, the woman should have basic life support and be transferred to a hospital setting as quickly as possible, unless a suitably trained healthcare professional is present with appropriate equipment and drugs in which case definitive resuscitation and treatment should be commenced. ✓

The treatment for anaphylaxis is 1:1000 adrenaline 500 micrograms (0.5 ml) intramuscularly. This dose is for intramuscular use only. ✓

What are the outcomes for mother and baby after maternal collapse?

Outcomes for mothers and babies depend on the cause of collapse, gestational age and access to emergency care, with survival rates being poorer if the collapse occurs out of hospital. In maternal cardiac arrest maternal survival rates of over 50% have been reported. *[New 2019]* C

Who should be on the team?

In addition to the general arrest team, there should also be a senior midwife, an obstetrician and an obstetric anaesthetist included in the team in cases of maternal collapse. ✓

The most senior obstetrician and senior anaesthetist should be called at the time of a cardiopulmonary arrest call. ✓

The neonatal team should be called early if delivery is likely (antepartum collapse over 22^{+0} weeks of gestation). ✓

Where the woman survives, a consultant intensivist should be involved as soon as possible. ✓

Clinical governance

Documentation

Accurate documentation is essential in all cases of maternal collapse, whether or not resuscitation is successful. ✓

Incident reporting

All cases of maternal collapse should generate a clinical incident form and the care should be reviewed through the clinical governance process. ✓

All cases of maternal death should be reported to MBRRACE-UK. *[New 2019]* D

Training

All generic life support training should consider the adaptation of CPR in pregnant women. ✓

All maternity staff should have annual formal multidisciplinary training in generic life support and the management of maternal collapse. ✓

Life support training improves resuscitation skills. A

Small group multidisciplinary interactive practical training is recommended to improve the management of maternal collapse. C

Debriefing

Debriefing is recommended for the woman, the family and the staff involved in the event. ✓

1. Purpose and scope

Maternal collapse is a rare but life-threatening event, with a wide ranging aetiology. The outcome primarily for the mother, but also the fetus, depends on prompt and effective resuscitation. The purpose of this guideline is to discuss the identification of women at an increased risk of maternal collapse and the different causes of maternal collapse, to delineate the initial and ongoing management of maternal collapse, and review the maternal and neonatal outcomes. It covers both hospital and community settings, and includes all gestations and the postpartum period. The resuscitation team and equipment, and training requirements will also be covered.

2. Introduction and background epidemiology

Maternal collapse is defined as an acute event involving the cardiorespiratory systems and/or central nervous systems, resulting in a reduced or absent conscious level (and potentially cardiac arrest and death), at any stage in pregnancy and up to 6 weeks after birth. Importantly, if maternal collapse which is not as the result of cardiac arrest is not treated effectively, maternal cardiac arrest can then occur. There is a robust and effective system for maternal mortality audit in the UK in the form of the Confidential Enquiry into Maternal Death performed by MBRRACE-UK (Mothers and Babies: Reducing Risk through Audits and Confidential Enquiries across the UK). However, the incidence of maternal collapse or severe maternal morbidity is unknown as morbidity data is not routinely collected. Even when it is, it is not collected in a standardised way to facilitate comparisons.[1] The incidence of cardiac arrest in pregnancy is much rarer than maternal collapse at around 1 in 36 000 maternities[2], with a case fatality rate of 42%. In a UK study, a total of 25% of cardiac arrests in pregnancy were secondary to anaesthesia and all were associated with a 100% survival rate.[2]

It is accepted that lessons can be learned from severe morbidity and near misses, and MBRRACE-UK now undertake targeted maternal morbidity confidential enquiries.[3] The UK Obstetric Surveillance System (UKOSS), run by the National Perinatal Epidemiology Unit, has made a significant contribution towards the study of rare events and maternal morbidity.[4] Severe maternal morbidity data were collected across Scotland for 10 years and published in 2014.[5] A woman was defined as having had a severe maternal morbidity event if there was a risk of maternal death

without timely intervention. The data showed a severe maternal morbidity rate of 7.3 in 1000 (730 in 100 000) maternities in 2012, but not all cases of severe maternal morbidity involved maternal collapse (although all cases of collapse were included in the figures). A publication from Ireland showed a severe maternal morbidity rate of 6.35 in 1000 (635 in 100 000) births in 2015.[6] These reports demonstrate that the rate of maternal morbidity has increased year on year. This is likely to reflect the changing demographics of women and better reporting, rather than a decline in care.[7] Between 2012 and 2014, the maternal mortality rate was 8.5 in 100 000 in the UK.[3] However, not all maternal collapse results in maternal death. Thus, the true rate of maternal collapse is unknown.

Whilst maternal collapse is such an uncommon event, the consequences are potentially devastating, therefore it is essential that the clinical team are skilled in initial effective resuscitation techniques, and are able to investigate and diagnose the cause of the collapse to allow appropriate, directed ongoing management. Unfortunately, in reports regarding morbidity[5,6] and the MBRRACE-UK report 2016,[3] areas of substandard care continue to be identified, including poor resuscitation skills. However, it should also be remembered that death and disability may result despite excellent care. It should be noted that vasovagal attacks and epileptic seizures[8] are the most common causes of maternal collapse and are not covered by this guideline.

3. Identification and assessment of evidence

This guideline was developed in accordance with standard methodology for producing Royal College of Obstetricians and Gynaecologists (RCOG) Green-top Guidelines. The Cochrane Library (including the Cochrane Database of Systematic Reviews and the Database of Abstracts of Reviews of Effects [DARE]), EMBASE, Trip, MEDLINE and PubMed (electronic databases) were searched for relevant randomised controlled trials (RCT), systematic reviews and meta-analyses. The search was restricted to articles published up to June 2018. The databases were searched using the relevant Medical Subject Headings (MeSH) terms, including all subheadings, and this was combined with a keyword search. Search words included, '*labor complication', '*maternal morbidity', '*maternal mortality', '*pregnancy complication' and '*heart arrest'. The search was restricted to humans and the English language. The National Library for Health and the National Guideline Clearinghouse were also searched for relevant guidelines and reviews.

Where possible, recommendations are based on available evidence. In the absence of published evidence, these have been annotated as 'good practice points'. Further information about the assessment of evidence and the grading of recommendations may be found in Appendix 1.

4. Clinical issues

4.1. Can women at risk of impending collapse be identified early?

An obstetric modified early warning score chart should be used for all women undergoing observation, to allow early recognition of the woman who is becoming critically ill. D

In some cases, maternal collapse occurs with no prior warning, although there may be existing risk factors which make this more likely. Antenatal care for women with significant medical conditions at risk of maternal collapse should include multidisciplinary team input with a pregnancy and birth management plan in place. Often there are clinical signs that precede collapse. In a previous report into maternal

Evidence level 4

deaths in the UK,[9] substandard care was often identified where these signs and symptoms were not recognised and acted upon. The MBRRACE-UK report published in 2016 recommended a national obstetric early warning scoring system should be introduced and used for all obstetric women, including those being cared for outside the obstetric setting. It also recommended that clinical judgment must be incorporated in that if the woman looks or feels unwell, despite the score, her care should be escalated.[3]

The first Modified Early Warning Score (MEWS systems)[10] were introduced on the basis that a deterioration in simple physiological vital signs will precede significant clinical deterioration and that early intervention will reduce morbidity.[11–15] They are now extensively used in acute settings and critical care,[16–18] although the optimal system has yet to be identified.[19]

Evidence level 2++

Despite this, the MEWS systems have not been demonstrated to be highly effective, even when their use has triggered input from a specialised medical emergency team.[20] Although their use is recommended by the National Institute for Health and Care Excellence (NICE)[21] and MBRRACE-UK[3] this is based on informal consensus rather than evidence.

The physiological changes of pregnancy may render the existing MEWS systems inappropriate,[22] and no validated system for use in pregnant women currently exists. Because of this, many maternity hospitals have developed their own modified MEWS system so local training is required, and there is ongoing work in the UK to try and develop a national obstetrics MEWS system. This, however, should be subjected to rigorous scrutiny to ensure that it is effective before it is universally implemented.

Evidence level 4

The National Early Warning Score 2 (NEWS2)[23] is endorsed by NHS England and NHS Improvement but is not recommendend for women who are more than 20 weeks pregnant because the physiological response to acute illness can be modified in pregnancy. With that in mind, it would seem reasonable to consider the use of NEWS2 in women who are less than 20 weeks pregnant. The timing of the use of NEWS2 postpartum is uncertain as the physiological changes of pregnancy are largely returned to pre-pregnancy levels by 48 hours although full return can take up to 6 weeks.

It is also important to consider the potential risks associated with the use of different scoring systems in the same organisation for the same patient depending on their stage of pregnancy.

A scoring system may still miss an unwell patient and a high level of clinical suspicion should be present if a patient looks unwell, even if her MEWS/Modified Early Obstetric Warning Score (MEOWS)/NEWS2 score is normal.

4.2. *What are the causes of maternal collapse?*

Maternal collapse can result from a number of causes. A systematic approach should be taken to identify the cause. D

Maternal collapse can result from many causes which may or may not be pregnancy related. A systematic approach to assessment facilitates identification of the cause of collapse. If the cause is reversible, the survival rates are greater[24] and those for which specific treatment exists must be rapidly considered. A systematic ABCDE approach should enable the clinical team to identify the most common causes of collapse. For ease of memory, these are divided by the Resuscitation Council (UK) in to the '4 T's' and

Evidence level 4

'4 H's'.[24] In pregnant women, eclampsia and intracranial haemorrhage should be added. Other specific obstetric causes could also be present and should be considered systematically (please see Appendix 2). Due to the lack of robust morbidity data regarding collapse, maternal deaths are often used as a reference point. The common causes of maternal collapse are discussed below, but this is not an exhaustive list, as this is beyond the scope of this guideline.

Evidence level 4

4.2.1. Haemorrhage

Major obstetric haemorrhage has an estimated incidence of 6 in 1000 maternities.[5] This is among the most common causes of maternal collapse and was responsible for 13 maternal deaths between 2012 and 2014.[3] Causes of major obstetric haemorrhage include postpartum haemorrhage, major antepartum haemorrhage from placenta praevia, placental abruption, uterine rupture and ectopic pregnancy. In most cases of massive haemorrhage leading to collapse, the cause is obvious, but concealed haemorrhage should not be forgotten, including following caesarean section and ruptured ectopic pregnancy. Other rarer causes of concealed haemorrhage include splenic artery rupture[25] and hepatic rupture. Blood loss is often difficult to estimate,[26,27] especially slow, steady bleeding, and fit, healthy women can tolerate significant loss prior to showing signs of decompensation.

Evidence level 2+

4.2.2. Thromboembolism

In the MBRRACE-UK report 2016,[3] deaths were the result of thromboembolism, making it the most common cause of direct maternal death. Appropriate use of thromboprophylaxis has improved maternal morbidity and mortality, but improvements in clinical risk assessment and prophylaxis are still required.[3,28]

Evidence level 2++

4.2.3. Amniotic fluid embolism (AFE)

UK data published in 2016 give an incidence of AFE of 1.7 per 100 000 maternities.[29] Survival rates seem to have improved significantly over time, from 14% in 1979,[30] to approximately 30% in 2005[31] and 81% by 2014.[29] However, neurological morbidity in survivors is well recognised.[29] The perinatal mortality rate in cases of AFE is 67 per 1000 total births.[29] It presents as collapse during labour or birth, or within (usually) 30 minutes of birth, in the form of acute hypotension, respiratory distress and acute hypoxia.[30] Seizures and cardiac arrest may occur. There are different phases to the disease progression,[32,33] which clearly depend on maternal survival. Initially, pulmonary hypertension may develop secondary to vascular occlusion either by debris or vasoconstriction. This often resolves and left ventricular dysfunction or failure develops. Coagulopathy often develops if the mother survives long enough, often giving rise to massive postpartum haemorrhage. If AFE occurs prior to birth, profound fetal distress develops acutely.[34] The underlying pathophysiological process has been compared to anaphylaxis or severe sepsis, and may be due to complement activation.[35,36] Diagnosis in nonfatal cases is clinical, as there is no established accurate diagnostic test premortem, although research continues in the area.[37]

Evidence level 2++

4.2.4. Cardiac disease

Cardiac disease was the most common overall cause of indirect maternal death in the MBRRACE-UK report 2016,[3] being responsible for 51 maternal deaths between 2012 and 2014. The majority of deaths secondary to cardiac causes occur in women with no previous history,[2,3] and almost one in five deaths occurred in an ambulance or accident and emergency department.[2,38] Therefore, paramedics and accident and emergency staff must be familiar with the management of maternal collapse. The main cardiac causes of maternal death are ischaemia and sudden arrhythmic cardiac death with a structurally normal heart.[3] Most cardiac events have preceding signs and symptoms. Aortic root dissection, although usually associated with an inherited aortopathy e.g. Ehlers-Danlos syndrome, can present in otherwise healthy women, and signs and symptoms, such as central chest or interscapular pain, a wide pulse pressure (mainly secondary to systolic hypertension) and a new cardiac murmur, must prompt appropriate imaging and, if required, referral to a cardiologist. The incidence of congenital and rheumatic heart disease in pregnancy is increasing, secondary to increased survival rates and with improved management of congenital heart disease. In addition, women with mechanical prosthetic heart valves are at particularly increased risk of complications in pregnancy.[39] These women should be cared for by an appropriately skilled and experienced multidisciplinary team, usually in regional centres.[2] Other cardiac causes include: cardiomyopathy; dissection of the coronary artery; acute left ventricular failure; infective endocarditis; and pulmonary oedema.

Evidence level 2++

4.2.5. Sepsis

Sepsis has been recognised for centuries as a significant cause of maternal morbidity and mortality, and substandard care continues to feature in the cases that result in death.[3] Bacteraemia, which can be present in the absence of pyrexia or a raised white cell count, can progress rapidly to severe sepsis and septic shock leading to collapse.[40,41] The most common organisms implicated in obstetric sepsis are the streptococcal groups A, B and D, pneumococcus and *Escherichia coli*.

Evidence level 2–

4.2.6. Drug toxicity and overdose

Drug toxicity and overdose should be considered in all cases of collapse. Substance misuse should be remembered as a potential cause of collapse especially outside of hospital. In terms of therapeutic drug toxicity, the commonly used drugs in obstetric practice are magnesium sulphate in the presence of renal impairment and local anaesthetic agents.

Toxic effects associated with local anaesthetics usually result from excessively high plasma concentrations. This can be either as a result of inadvertent intravenous injection, or systemic absorption of toxic amounts administered via appropriate (epidural, local infiltration etc.) routes. On intravenous injection, convulsions and cardiovascular collapse may occur very rapidly. Local anaesthetic toxicity resulting from systemic absorption of the local anaesthetic may occur sometime after the initial injection. Effects initially include a feeling of inebriation and lightheadedness followed by sedation, circumoral paraesthesia and twitching; convulsions can occur in severe toxicity. Signs of severe toxicity include sudden loss of consciousness, with or without tonic-clonic convulsions, and cardiovascular collapse; sinus bradycardia, conduction blocks, asystole and ventricular tachyarrhythmias can all occur.[42]

Evidence level 4

In terms of local anaesthetics, total spinal block or high spinal/epidural block are rare. A high index of suspicion is needed in cases of maternal collapse following spinal anaesthesia or epidural top up. Appropriate training of medical and midwifery staff to recognise the signs and symptoms of high block is essential.

4.2.7. Eclampsia

Eclampsia as the cause of maternal collapse is usually obvious in the inpatient setting. Often the diagnosis of pre-eclampsia has already been made and the seizure witnessed. In the community setting, fitting after 20 weeks' gestation may be attributable to eclampsia, notably where there is no known history of epilepsy. However, epilepsy should always be considered in cases of maternal collapse associated with seizure activity.[8]

4.2.8. Intracranial haemorrhage

Intracranial haemorrhage is a significant complication of uncontrolled, particularly systolic, hypertension, but can also result from ruptured aneurysms and arteriovenous malformations. The initial presentation may be maternal collapse, but often severe headache precedes this.

4.2.9. Anaphylaxis

In cases of collapse assumed to be due to anaphylaxis mast cell tryptase levels can be useful in confirming the diagnosis. ✓

Anaphylaxis is a severe, life-threatening generalised or systemic hypersensitivity reaction,[43] resulting in respiratory, cutaneous and circulatory changes, and possibly gastrointestinal disturbance and collapse. There is significant intravascular volume redistribution, which can lead to decreased cardiac output. Acute ventricular failure and myocardial ischaemia may occur. Upper airway occlusion secondary to angioedema, bronchospasm and mucous plugging of smaller airways all contribute to significant hypoxia and difficulties with ventilation. Common triggers are a variety of drugs, latex, animal allergens and foods. The incidence of severe perioperative obstetric anaphylaxis is between 1 and 3.5 per 100 000, with a mortality rate of approximately 1%.[44] Anaphylaxis is likely when all of the following three criteria are met:

- sudden onset and rapid progression of symptoms
- life-threatening airway and/or breathing and/or circulation problems
- skin and/or mucosal changes (flushing, urticaria, angioedema).

Exposure to a known allergen for the woman supports the diagnosis, but many cases occur with no previous history. Mast cell tryptase levels can be useful in confirming the diagnosis. As a minimum, 1 sample at 1–2 hours after the start of symptoms should be taken. Ideally though 3 timed samples should be taken: as soon as possible after resuscitation has started (without delaying resuscitation); 1–2 hours after the start of symptoms; 24 hours later.[44]

Evidence level 4

4.2.10. Other causes

These include hypoglycaemia, hyponatraemia[45] and other metabolic and electrolyte disturbances. Other causes of hypoxia include airway obstruction secondary to aspiration or foreign body, air embolism, tension pneumothorax, cardiac tamponade secondary to trauma or dissection, and hypothermia. From an anaesthetic perspective, the main causes of collapse would be local anaesthetic toxicity or failed tracheal intubation. There will be other very unusual and rare causes of maternal collapse, but detailed discussion of all causes is beyond the scope of this guideline.

4.3. What are the physiological and anatomical changes in pregnancy that affect resuscitation?

It is essential that anyone involved in the resuscitation of pregnant women is aware of the physiological differences. This includes pre-hospital care clinicians, paramedics and emergency medicine department staff. ✓

Pregnant women undergo a variety of physiological changes that can accelerate the development of hypoxia and acidosis, and make ventilation more difficult.[46] These changes are listed in Appendix 3,[47] and combined with other physical changes, make resuscitation during pregnancy more challenging. It is essential that anyone involved in the resuscitation of a pregnant woman is aware of these differences. This includes paramedics, critical care staff and emergency medicine department staff.

Evidence level 2+

4.3.1. Aortocaval compression

Aortocaval compression significantly reduces cardiac output from 20 weeks of gestation onwards and the efficacy of chest compressions during resuscitation. C

From around 20 weeks of gestation onwards the gravid uterus reduces venous return in the supine position. As a consequence, cardiac output is reduced by up to 30–40%.[48] Supine hypotension itself can precipitate maternal collapse, which is usually reversed by turning the woman into the left lateral position.

Evidence level 2+

When cardiopulmonary arrest occurs, chest compressions are needed to produce a cardiac output. In the nonpregnant situation, they achieve around 30% of the normal cardiac output.[49–51] Aortocaval compression further reduces cardiac output to approximately 10% of the nonpregnant cardiac output.[52] Therefore, cardiopulmonary resuscitation (CPR) is less likely to be effective in a woman who is at 20 or more weeks of gestation.

Evidence level 2+

4.3.2. Respiratory changes

Changes in lung function, diaphragmatic splinting and increased oxygen consumption make pregnant women become hypoxic more readily and make ventilation more difficult. C

The increased progesterone level in pregnancy increases the respiratory drive,[53,54] leading to an increase in tidal volume and minute ventilation. Splinting of the diaphragm by the enlarged uterus reduces the functional residual capacity (FRC) and also makes ventilation more difficult. Reduction in FRC along with the markedly increased oxygen consumption of the fetoplacental unit, means that pregnant women become hypoxic much more rapidly during periods of hypoventilation.

Evidence level 2+

4.3.3. Intubation

Difficult intubation is more likely in pregnancy.

C

Weight gain in pregnancy, large breasts inhibiting the working space and laryngeal oedema can all contribute to making intubation more difficult.[55,56]

Evidence level 2+

4.3.4. Aspiration

Pregnant women are at an increased risk of aspiration.

C

Pregnant women are at a significantly higher risk of regurgitation and aspiration, secondary to the progesterone effect relaxing the lower oesophageal sphincter along with the raised intra-abdominal pressure secondary to the gravid uterus. During labour or following maternal opioid administration there can also be a delay in gastric emptying. Aspiration pneumonitis in pregnant women, known as Mendelsson's syndrome,[57] can be severe. The risks can be minimised by early intubation with effective cricoid pressure, and the use of H_2 antagonists and antacids prophylactically in all women considered to be at high risk of obstetric intervention during labour.

Evidence level 2+

4.3.5. Circulation

The increased cardiac output and hyperdynamic circulation of pregnancy mean that large volumes of blood can be lost rapidly, especially from the uterus which receives 10% of the cardiac output at term. Otherwise healthy women tolerate blood loss remarkably well and can lose up to 35% of their circulation before becoming symptomatic, and often maternal tachycardia may be the only sign of hypovolaemia until very late in the haemorrhage. Blood loss is tolerated less well if there is a pre-existing maternal anaemia,[58] and clotting is less efficient if there is significant anaemia. Concealed bleeding and underestimation of loss means that intervention is often delayed. Where signs of hypovolaemia have been subtle, hypovolaemia as the cause of maternal cardiopulmonary arrest may go unrecognised.

Evidence level 4

4.4. What is the optimal initial management of maternal collapse?

4.4.1. Resuscitation in maternal collapse

Maternal collapse resuscitation should follow the Resuscitation Council (UK) guidelines using the standard ABCDE approach, with some modifications for maternal physiology, in particular relief of aortocaval compression.

D

If maternal cardiac arrest occurs in the community setting, basic life support should be administered and rapid transfer arranged. ✓

In the UK, resuscitation is conducted according to the guidelines of the Resuscitation Council (UK). These guidelines include: Adult Basic Life Support; Adult Advanced Life Support; and Automated External Defibrillation algorithms and recommendations.[24] These guidelines were updated in 2015 by international experts under the auspices of the International Liaison Committee on Resuscitation[59] and are used in the resuscitation of a pregnant woman.

Evidence level 4

Maternal collapse can occur in the community setting, and pre-hospital care of the collapsed pregnant patient should follow the same guidance from the Resuscitation Council (UK) listed above and will be delivered by ambulance paramedics and/or pre-hospital care clinicians. The care standards delivered in the pre-hospital setting have been well documented in the UK Ambulance Services Clinical Practice Guidelines Pocket Book and Emergency Birth in the Community guideline.[60,61]

In the event of maternal collapse, signs of life should be sought if the assessor is confident in this (check for breathing and carotid pulse). If the assessor is not confident or there is any doubt in the detection of signs of life, cardiopulmonary resuscitation should be commenced. However, if signs of life are detected, a standard ABCDE approach should be taken. The woman should be placed in the left lateral position, obstetric review should be sought, the need for oxygen therapy should be assessed and adequate vascular access should be gained. An alert, verbal stimulus, pain stimulus, unresponsive (AVPU) assessment should be undertaken as an alteration of consciousness can be a sign of critical illness. The cause of the maternal collapse should be rapidly identified and treated to prevent potential progression to maternal cardio-respiratory arrest. Ongoing regular ABCDE assessment should be performed as the risk of progression to cardiac arrest remains until the cause of the collapse is treated. Assessment of fetal wellbeing should be undertaken after ABCDE assessment (Appendix 4).

If signs of life are not detected in the hospital setting, a cardiac arrest should be declared and the cardiac arrest team called. An emergency call for the obstetric, obstetric anaesthetic and neonatal (if undelivered and more than 22^{+0} weeks of gestation) resuscitation teams should be made. The consultant obstetrician and consultant anaesthetist should also attend. Standard basic life support should be initiated.[62]

Evidence level 4

From 20 weeks of gestation, changes in maternal physiology mean that adaptations are made to the resuscitation process. While Resuscitation Council (UK) algorithms for generic, paediatric and neonatal life support are available in standardised posters, adaptations for maternal resuscitation are addressed but are not available in algorithmic and poster form. For this reason, the Resuscitation Council (UK) algorithm for advanced life support has been modified by the authors and is included in Appendix 4 of this guideline.

4.4.2. Relieving aorto-caval compression

Manual displacement of the uterus to the left is effective in relieving aortocaval compression in women above 20 weeks' gestation or where the uterus is palpable at or above the level of the umbilicus. This permits effective chest compressions in the supine position in the event of cardiac arrest. D

A left lateral tilt of the woman from head to toe at an angle of 15–30° on a firm surface will relieve aortocaval compression in the majority of pregnant women and still allow effective chest compressions to be performed in the event of cardiac arrest. C

In cases of major trauma, the spine should be protected with a spinal board before any tilt is applied. In the absence of a spinal board, manual displacement of the uterus should be used. ✓

There are essential adaptations to the management of a collapsed pregnant woman because of the physiological and anatomical changes of pregnancy.

After 20 weeks' gestation or when the uterus is palpable at or above the level of the umbilicus, manual uterine displacement is the preferred method to reduce compression of the inferior vena cava and aorta by the gravid uterus if performed correctly. The technique should be performed using an 'up, off and over' method.[63,64] This is achieved by placing a hand below the uterus on the maternal right and pushing the uterus slightly upwards and to the left. This maintains the woman in a supine position, allowing for continuous effective cardiac compressions if necessary.[65] Evidence level 2+

A left lateral tilt of the woman from head to toe at an angle of 15–30° to relieve aortocaval compression[66,67] can be achieved on a tilting operating table, with a solid wedge (of an appropriate size)[68] and spinal board, and allow for effective chest compressions to be performed[67]. In the absence of these, manual displacement of the uterus is preferable. Using soft surfaces, such as a bed, or objects, such as pillows or blankets, are not nearly as effective, compromise effective chest compressions, and should not be used (a video of the procedure can be found at https://www.youtube.com/watch?v=2VyqGqDNlLc). Evidence level 2+

4.4.3. Airway

Intubation in an unconscious woman with a cuffed endotracheal tube should be performed immediately by an experienced anaesthetist. ✓

The airway in pregnancy is more vulnerable because of the increased risk of regurgitation and aspiration.[63,69] For this reason, it is important to clear and protect the airway as early as possible. Intubation with a cuffed endotracheal tube should then be performed. This will protect the airway, ensure good oxygen delivery and facilitate more efficient ventilation. Intubation can be more difficult in pregnancy, so this should be undertaken by someone with appropriate skills. Failed intubation is more common in the pregnant than nonpregnant patient and a plan for failed intubation should always be considered. A full description of the failed intubation drill is available from the Difficult Airway Society.[70] In brief: Maintain oxygenation; Call for help; Supraglottic airway device; Front of Neck access. During cardiac arrest in a nonpregnant woman it is acceptable to use a supraglottic device, such as a laryngeal mask airway as an alternative to the endotracheal tube.[71] In pregnant women, physiological changes in the airway, such as hyperaemia, hypersecretion and oedema lead to increased friability of the airway mucosa causing bleeding and difficulties in visualisation for intubation.[69] Pregnant women are also more likely to regurgitate and aspirate in the absence of a secured airway (endotracheal tube) than a nonpregnant woman, and thus, the early involvement of an appropriately skilled anaesthetist remains best practice.[69] Evidence level 4

Waveform capnography must be used to confirm and continually monitor tracheal tube placement, and may be used to monitor the quality of CPR and to provide an early indication of return of spontaneous circulation.[24]

Appendix 5 of this guideline presents suggested equipment that should be available for cases where airway management may be difficult.

4.4.4. Breathing

Supplemental high flow oxygen should be administered as soon as possible to counteract rapid deoxygenation. ✓

Bag and mask ventilation or insertion of a simple supraglottic airway should be undertaken until intubation can be achieved. ✓

Maternal physiological changes lead to increased oxygen requirements. Furthermore, in maternal collapse, reduced oxygen reserve and a reduced functional residual capacity leads to deoxygenation occurring more rapidly than in nonpregnant women. Therefore, supplemental oxygen should be added with a gas flow of 10–15 l per minute to whatever method of ventilation is being employed.[62]

Evidence level 2++

Ventilation, using a face mask, or a supraglottic airway device and self-inflating bag, or via a cuffed endotracheal tube, may be more difficult because of the physiological changes of pregnancy as previously described. It can also be difficult to see the chest rise.

4.4.5. Circulation

If the airway is clear and there is no breathing, chest compressions should be commenced immediately. B

Two wide-bore cannulae (minimum 16 gauge) should be inserted as soon as possible. If peripheral venous access is not possible, early consideration of central venous access, intraosseous access or venous cutdown should be considered. ✓

There should be an aggressive approach to volume replacement, although caution should be exercised in the context of pre-eclampsia or eclampsia. ✓

Abdominal ultrasound by a skilled operator can assist in the diagnosis of concealed haemorrhage. C

The same defibrillation energy levels should be used as in a nonpregnant woman. B

Chest compressions should be commenced immediately in the absence of a cardiac output.[72] Compressions may be made difficult because of obesity and if the woman is in the tilted position. Hand position should be over the centre of the chest and it is important to ensure that the direction of compression is perpendicular to the chest wall. If a left lateral tilt is employed then the angle of tilt must be taken into account when performing chest compressions. Immediate and competent chest compressions have been found to have a direct impact on maternal outcome.[72]

Evidence level 2++

In total, 30 chest compressions (at a rate of 100–120 per minute) should be performed for every two ventilation breaths initially. If there are two rescuers, one should be responsible for chest compressions and ventilation breaths, whilst the other should ensure aortocaval decompression with manual uterine displacement. Once intubation is performed, the ratio of chest compressions to ventilation breaths should be desynchronised. Ventilation should be at a rate of 10 breaths per minute with continuous chest compressions at 100–120 per minute. Because chest compressions are not as effective after 20 weeks of gestation, there should be early recourse to delivery of the fetus and placenta if CPR is not effective.[24] In woman with a very high BMI chest compressions can be performed over the head of the woman if there is sub-optimal rescuer positioning.[73]

Evidence level 2++

Ideally, early vascular access will be obtained with wide-bore intravenous cannulae inserted above the level of the diaphragm. This allows the administration of fluids to not be affected by aortocaval compression. If peripheral venous access is difficult, there should be early consideration of central venous access, intraosseous access[74] or venous cutdown to aid volume replacement.

Haemorrhage is the most common cause of maternal collapse, and is a consequence of other causes of collapse. There must be a high index of suspicion for bleeding and awareness of the limitations of maternal clinical signs. Caution must be exercised in the clinical context of severe pre-eclampsia and eclampsia, where fluid overload can contribute to poor outcome. In the case where significant haemorrhage, and pre-eclampsia or eclampsia exist, careful fluid management is essential.

Very occasionally, ultrasound by a skilled operator can assist in the diagnosis of free fluid associated with intra-abdominal bleeding, although laparotomy should not be delayed if the findings are negative and/or the index of suspicion is high.[75–78] This, however, should not interfere with the resuscitation process.

Evidence level 2+

If defibrillation is required, the same settings should be used as in the nonpregnant adult, as there is no change in thoracic impedance.[79] Adhesive defibrillator pads are preferable to defibrillator paddles, and the left defibrillation pad should be applied lateral to the left breast. If the woman's breasts are large or engorged, defibrillator pads may need to be placed on the anterior and posterior precordium to optimise defibrillation energy transfer.[72] The energy from the defibrillation shock is directed across the heart and there is no evidence that shocks from a direct current defibrillator have an adverse effect on the fetus. Uterine monitors should be removed before shock delivery.

Evidence level 2++

4.4.6. Drugs

There should be no alteration in algorithm drugs or doses used in the Resuscitation Council (UK) protocols. ✓

4.4.7. Other considerations

Common, reversible causes of maternal cardiopulmonary arrest should be considered throughout the resuscitation process. D

Resuscitation efforts should be continued until a decision is taken by the consultant obstetrician and consultant anaesthetist to discontinue resuscitation efforts. This decision should be made in consensus with the cardiac arrest team. ✓

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.[24] Evidence level 4

4.5. When, where and how should perimortem caesarean section (PMCS) be performed?

In women over 20 weeks of gestation, if there is no response to correctly performed CPR within 4 minutes of maternal collapse or if resuscitation is continued beyond this, then PMCS should be undertaken to assist maternal resuscitation. Ideally, this should be achieved within 5 minutes of the collapse. D

PMCS should not be delayed by moving the woman. It should be performed where maternal collapse has occurred and resuscitation is taking place. ✓

The operator should use the incision, which will facilitate the most rapid access. This may be a midline vertical incision or a suprapubic transverse incision. ✓

A scalpel and umbilical cord clamps (or alternative ligatures) should be available on the resuscitation trolley in all areas where maternal collapse may occur, including the accident and emergency department. ✓

The concept of PMCS was introduced by Katz et al.[80] in 1986. This research group initially focused on infant survival and found that 69% of infants survived when PMCS was performed within 5 minutes. However, when Katz et al. explored maternal outcomes, they found that hypoxic brain injury only occurred if PMCS was performed after 6 minutes. Although the research basis for this recommendation is scarce, the rationale for this timescale is that pregnant women become hypoxic more quickly than nonpregnant women, and irreversible brain damage can ensue within 4–6 minutes. The term 'resuscitative hysterotomy'[81] has been introduced by non-obstetric clinicians (for example, emergency medicine clinicians and paramedics) in the trauma and emergency department environments, as the procedure is primarily used to assist maternal resuscitation rather than to save the fetus. Obstetricians should be aware of this terminology to ensure effective communication.[82] The gravid uterus impairs venous return and thus reduces cardiac output by approximately 60% secondary to aortocaval compression.[83] Delivery of the fetus and placenta reduces oxygen consumption, improves venous return and cardiac output, facilitates chest compressions and makes ventilation easier. It also allows for internal chest compressions by inserting the hand through the open abdomen up to the diaphragm and compressing the posterior aspect of the heart against the Evidence level 4

chest wall. This improves cardiac output beyond that achieved in closed chest compressions.[84] At less than 20 weeks of gestation there is no proven benefit from delivery of the fetus and placenta. PMCS should be considered a resuscitative procedure, to be performed primarily in the interests of maternal survival.

Evidence level 4

Delivery within 5 minutes of maternal collapse improves the chances of survival for the baby. If maternal resuscitation is continuing beyond 4 minutes of the collapse, delivery of the fetus and placenta should be performed as soon as possible to aid this, even if the fetus is already dead. Case series have shown that swift delivery of the baby improves maternal outcome even after 5 minutes have elapsed from maternal collapse.[85] There is, of course, the possibility that the outcome could be that the surviving child has sustained damage in an attempt to preserve the life of the mother.

Evidence level 2+

Time should not be wasted by moving the woman to an operating theatre; a PMCS can be performed anywhere, with a scalpel being the only essential equipment required.[86,87] With no circulation, blood loss is minimal, and no anaesthetic is required. If resuscitation is successful following birth, there should be prompt transfer to an appropriate environment at that point, as well as anaesthesia and sedation, to control ensuing haemorrhage and complete the operation. The doctrine of 'best interests of the patient' would apply to conduct of this procedure being carried out without consent.

Evidence level 4

In terms of the best incision to use, a midline abdominal incision and a classical uterine incision will give the most rapid access. However, many will be unfamiliar with this approach and as delivery can be achieved rapidly with a transverse approach, the operator should use the approach they are most comfortable with.[86] Manual uterine displacement can be stopped immediately prior to incision. If resuscitation is successful, the uterus and abdomen should be closed in the usual way to control blood loss and minimise the risk of infection. Where the resuscitation is not successful, the case should be discussed with the coroner or procurator fiscal to determine whether a postmortem is required before any medical devices, such as lines and endotracheal tube are removed, as per the Royal College of Pathologists recommendations.[88]

Evidence level 2++

To ensure there are no delays in executing a PMCS when indicated, the equipment necessary should be immediately available on the resuscitation trolley. All that is required is a fixed blade scalpel and two clamps for the umbilical cord. In the absence of a specific tray, a scalpel alone will enable delivery of the fetus and placenta, and cutting of the umbilical cord, which can then be manually compressed until a clamp is found if the baby is alive.

4.6. What does the ongoing management consist of?

Senior staff with appropriate experience should be involved at an early stage. ✓

Transfer should be supervised by an adequately skilled team with appropriate equipment. ✓

Ongoing management depends on the underlying cause of the collapse and appropriate senior staff must be involved early. It is essential the woman is transferred to an appropriate environment to ensure optimal ongoing care. This would usually mean transfer to a high dependency or critical care area with appropriate staff and monitoring facilities.[68] Please see Appendix 6 for more information on post collapse management.

4.6.1. Haemorrhage

In the case of maternal collapse secondary to antepartum haemorrhage, the fetus and placenta should be delivered promptly to allow control of the haemorrhage. ✓

In the case of massive placental abruption, caesarean section may occasionally be indicated even if the fetus is dead to allow rapid control of the haemorrhage. ✓

Intravenous tranexamic acid significantly reduces mortality due to postpartum haemorrhage. A

The ongoing management of major antepartum haemorrhage is comprehensively covered in the RCOG Green-top Guideline No. 63 *Antepartum Haemorrhage*.[89]

Management of collapse secondary to massive haemorrhage as a result of placenta praevia should be managed in accordance with the RCOG Green-top Guideline Nos. 27a and 27b *Placenta Praevia and Placenta Praevia Accreta: Diagnosis and Management* and *Vasa Praevia: Diagnosis and Management*.[90,91] Evidence level 4

The ongoing management of major postpartum haemorrhage is comprehensively covered in the RCOG Green-top Guideline No. 52 *Postpartum Haemorrhage: Prevention and Management*.[92]

A large randomised controlled study[93] including more than 20 000 women comparing 1 g intravenous tranexamic acid with placebo in cases of postpartum haemorrhage demonstrated a significant reduction in death from haemorrhage, particularly if given within 3 hours. Evidence level 1++

4.6.2. Venous thromboembolism

Massive pulmonary embolism should be treated according to RCOG Green-top Guideline No. 37b *Acute Management of Thrombosis and Embolism during Pregnancy and the Puerperium*. D

The specific management of massive pulmonary embolism is covered in the RCOG Green-top Guideline No. 37b *Acute Management of Thrombosis and Embolism during Pregnancy and the Puerperium*.[94] This includes the use of thrombolysis. Evidence level 4

4.6.3. Amniotic fluid embolism (AFE)

The management of AFE is supportive rather than specific, as there is no proven effective therapy. ✓

Early involvement of senior experienced staff, including obstetricians, anaesthetists, haematologists and intensivists, is essential to optimise outcome. ✓

Coagulopathy needs early, aggressive treatment, including the use of fresh frozen plasma. ✓

Recombinant factor VII should only be used if coagulopathy cannot be corrected by massive blood component replacement as it has been associated with poorer outcome in women with AFE. C

There is no proven effective therapy for the management of AFE. It is therefore supportive rather than specific.[3,95] Evidence level 2++

In addition to resuscitation and supportive measures, arrhythmias may develop and will require standard treatment. Inotropic support is likely to be needed and measurement of cardiac output may help direct therapy and avoid fluid overload; fluid overload will exacerbate pulmonary oedema and increase the risk of acute respiratory distress syndrome. High filling pressures are indicative of a failing left ventricle.

In women with AFE, those treated with recombinant factor VII were found to have worse outcomes than in those not treated with recombinant factor VII. Therefore, recombinant factor VII should only be used in patients with AFE when haemorrhage cannot be stopped by massive blood component replacement.[29,96]

If undelivered, delivery of the fetus and placenta should be performed as soon as possible. The incidence of uterine atony is increased in this condition and contributes to the postpartum haemorrhage. This should be managed as described in the RCOG Green-top Guideline on postpartum haemorrhage.[92] Evidence level 2+

Various other therapies have been tried, including steroids, heparin, plasmapheresis and haemofiltration, usually in single cases. As such, there is no robust evidence to support their use.[29]

4.6.4. Cardiac disease

After successful resuscitation, cardiac cases should be managed by an expert cardiology team. ✓

After initial resuscitation, the ongoing management of cardiac disease is similar to that in the nonpregnant state, although in many cases, delivery will be necessary to facilitate this.

Although thrombolysis can be associated with significant bleeding from the placental site, it should be given to women with acute coronary insufficiency, although caution should be exercised in the perioperative period.[97] If available, percutaneous angioplasty allows accurate diagnosis and definitive therapy. Evidence level 4

4.6.5. Sepsis

Septic shock should be managed in accordance with the Surviving Sepsis Campaign guidelines. D

The Surviving Sepsis Campaign has updated the management of sepsis and septic shock.[98] The speed and appropriateness of therapy administered in the initial hours after severe sepsis develops are likely to influence outcome with early resuscitation improving survival rates. A multidisciplinary team approach is required, including midwives, consultant obstetricians, anaesthetists, haematologists, intensivists and microbiologists. The following 'Care

Bundle' should be applied immediately or within 6 hours, and has been shown to significantly improve survival rates:[99,100]

1. Measure serum lactate.
2. Obtain blood cultures and culture swabs prior to antibiotic administration.
3. Administer broad spectrum antibiotic(s) within the first hour of recognition of severe sepsis and septic shock according to local protocol.
4. In the event of hypotension and/or lactate more than 4 mmol/l:
   a. Begin rapid administration of an initial minimum of 30 ml/kg of crystalloid to be completed within 3 hours of diagnosis.
   b. once adequate volume replacement has been achieved, a vasopressor (noradrenaline, with vasopressin or adrenaline in addition, if required) and/or an inotrope (for example, dobutamine) may be used to maintain mean arterial pressure more than 65 mmHg.

Further management consists of:

5. In the event of hypotension despite fluid resuscitation (septic shock) and/or lactate more than 4 mmol/l:
   a. dynamic variables of fluid status such as transoesophageal Doppler and lithium dilution cardiac output (LiDCO) are preferred to static variables like central venous pressure or pulmonary artery occlusion pressure and the use of central venous pressure alone to guide fluid resuscitation can no longer be justified
   b. consider steroids if unresponsive to adequate fluid resuscitation and vasopressor therapy.
   c. Maintain oxygen saturation at more than 94% (88%–92% in women at risk of hypercapnic respiratory failure) with facial oxygen.[94] Consider transfusion if haemoglobin less than 70 g/l.

Ongoing management involves continued supportive therapy, removing the septic focus, administration of blood products if required, and thromboprophylaxis.[99] Evidence level 1+

4.6.6. Drug overdose and toxicity

Many drug overdoses have treatments specific to the drug in question and appropriate help should be sought in the management of such cases, including liaising with Toxbase and speaking to GP/local pharmacist. In obstetric practice, the two main drugs that can give rise to overdose or toxic problems are magnesium sulphate and local anaesthetic agents.

4.6.6.1. Magnesium sulphate

The antidote to magnesium toxicity is 10 ml 10% calcium gluconate or 10 ml 10% calcium chloride given by slow intravenous injection. ✓

Magnesium sulphate toxicity should be managed by slow intravenous injection of 10 ml 10% calcium gluconate or 10 ml 10% calcium chloride.[101]

4.6.6.2. *Local anaesthetic agents*

If local anaesthetic toxicity is suspected, stop injecting immediately. ✓

Lipid rescue should be used in cases of collapse secondary to local anaesthetic toxicity. C

Intralipid® 20% should be available in all hospitals offering maternity services. ✓

Manage arrhythmias as usual, recognising that they may be very refractory to treatment. ✓

All cases of lipid rescue should be reported to NHS Improvement and the Lipid Rescue site. ✓

The mechanism by which lipids reverse local anesthetic cardiotoxicity may be increasing clearance from cardiac tissue. This nonspecific, observed extraction of local anesthetics from aqueous plasma or cardiac tissues is termed a 'lipid sink.' Another proposed mechanism is that lipids counteract local anesthetic inhibition of myocardial fatty acid oxidation, thereby enabling energy production and reversing cardiac depression.

Treatment of cardiac arrest with lipid emulsion[42,102] consists of an intravenous bolus injection of Intralipid® (Baxter Healthcare Corporation, Deerfield, Illinois, USA) 20% 1.5 ml/kg over 1 min (100 ml for a woman weighing 70 kg) followed by an intravenous infusion of Intralipid® 20% 15 ml/kg/h (1000 ml.h^{-1} for a woman weighing 70 kg). The bolus injection can be repeated twice at 5-minute intervals if an adequate circulation has not been restored (a further two 100 ml boluses at 5-minute intervals for a woman weighing 70 kg). After another 5 minutes, the infusion rate should be increased to 30 ml/kg/hr if an adequate circulation has not been restored. Do not exceed a maximum cumulative dose of 12 ml/kg (840 ml for a woman weighing 70 kg). CPR should be continued throughout this process until an adequate circulation has been restored. This may take over 1 hour.[103] Evidence level 2+

Prolonged resuscitation may be necessary, and it may be appropriate to consider other options. The first-line treatment should be lipid emulsion, but if the facilities are available, some may consider the use of cardiopulmonary bypass.

All cases of lipid rescue should be reported to NHS Improvement (www.nrls.npsa.nhs.uk) and to the Lipid Rescue site (www.lipidrescue.org). The Association of Anaesthetists of Great Britain & Ireland provides guidance on the management of severe local anaesthetic toxicity, which can be used locally.[103]

4.6.7. Eclampsia

Eclampsia should be managed in accordance with the NICE Clinical Guideline 107 *Hypertension in Pregnancy: Diagnosis and Management*. D

Guidance regarding the management of eclampsia can be found in the NICE guideline on hypertension in pregnancy.[104]

4.6.8. Intracranial haemorrhage

Neuroradiologists and neurosurgeons should be involved in the care of pregnant women with intracranial haemorrhage at the earliest opportunity. ✓

Expert neuroradiology is required to establish an accurate diagnosis, and management is the same as in nonpregnant women, although delivery may be necessary to facilitate this.[105] Evidence level 4

4.6.9. Anaphylaxis

In cases of anaphylaxis, all potential causative agents should be removed, and the ABCDE approach to assessment and resuscitation followed. ✓

If the anaphylactic reaction occurs in the community, the woman should have basic life support and be transferred to a hospital setting as quickly as possible, unless a suitably trained healthcare professional is present with appropriate equipment and drugs in which case definitive resuscitation and treatment should be commenced. ✓

The treatment for anaphylaxis is 1:1000 adrenaline 500 micrograms (0.5 ml) intramuscularly. This dose is for intramuscular use only. ✓

In cases of anaphylaxis, all potential causative agents should be removed, and the ABCDE approach followed.[44,106] Evidence level 4

Adrenaline treatment can be repeated after 5 minutes if there is no effect.[44,106] In experienced hands, 50 microgram bolus (0.5 ml of 1:10 000 solution) can be titrated intravenously. Adjuvant therapy consists of chlorphenamine 10 mg and hydrocortisone 200 mg. Both are given intramuscularly or by slow intravenous injection.[44,106] Evidence level 4

4.7. What are the outcomes for mother and baby?

Outcomes for mothers and babies depend on the cause of collapse, gestational age and access to emergency care, with survival rates being poorer if the collapse occurs out of hospital. In maternal cardiac arrest maternal survival rates of over 50% have been reported. C

Due to the lack of robust population data, it is not possible to be accurate regarding maternal and neonatal outcomes of maternal collapse. There remains a significant reporter bias in publications relating to the topic. The MBRRACE-UK Saving Lives and Improving Mothers' Care report and UK Obstetric Surveillance System studies provide robust data for maternal survival for individual conditions, such as AFE and sepsis. The general trend of reducing numbers of maternal deaths despite a plateau in the number of maternities demonstrated by MBRRACE-UK suggests that survival from maternal collapse is improving.[2,3]

A UKOSS prospective cohort study identified 66 cardiac arrests between July 2011 and June 2014 resulting in an incidence of 2.78 per 100 000 maternities.[39] In all, 28 women died (case fatality rate 42%). Basic and Evidence level 2+

advanced life support were quickly delivered. Women who collapsed at home were more likely to die. PMCS was performed on 49 women (11 of these performed in the emergency department). Time intervals between collapse and PMCS was significantly shorter in women who survived compared with those who died (median interval, 3 minutes versus 12 minutes; $P = 0.001$).

The latest systematic review to study the efficacy of PMCS was published in 2012 by Einav et al.[87] This review identified a total of 80 relevant publications that reported the outcome of 94 women. In 31.7% of identified cases of PMCS, the procedure was found to be of benefit for maternal or fetal survival. No harm was found in any of the 94 women who underwent PMCS. When analysing maternal outcome, 54.3% of women survived until hospital discharge and 42.6% of women survived with good to moderately impaired neurological outcome. Although the study was unable to validate the need to deliver by 5 minutes duration, it was able to demonstrate that maternal outcomes were more favourable if performed within 10 minutes of maternal cardiac arrest (OR 7.42; $P < 0.05$). Neonatal survival was also associated with a shorter mean cardiac arrest to delivery time (14[±11] minutes versus 22[±13] minutes). Neonatal survival was only found in women who suffered cardiac arrest in hospital and there were reports of neonatal survival where delivery was performed 30 minutes after maternal cardiac arrest.

The MBRRACE-UK report 2016 described the neonatal outcomes of the 32 babies born by PMCS.[3] Of these babies, 19 were delivered by caesarean section after 32 weeks of gestation; nine of the 19 babies survived. Of the 13 babies born by PMCS at 32 weeks of gestation or less, only three survived. Therefore, the overall neonatal survival of babies delivered by PMCS was 38%. Survival was directly associated with advanced gestation and delivery within a suitable birthing or critical care setting.

Evidence level 2+

There have been successful cases of somatic support after maternal brain death to facilitate neonatal outcome.[107] The longest being from 15 weeks of gestation to birth at 32 weeks of gestation.[108] This process is not without difficulties, both in medical terms and ethically,[109] and what is not known is how many such cases have not been successful. In view of the complex nature of such cases, a multidisciplinary discussion including the family should be conducted in each case.

Evidence level 2–

4.8. Who should be on the team?

In addition to the general arrest team, there should also be a senior midwife, an obstetrician and an obstetric anaesthetist included in the team in cases of maternal collapse. ✓

The most senior obstetrician and senior anaesthetist should be called at the time of a cardiopulmonary arrest call. ✓

The neonatal team should be called early if delivery is likely (antepartum collapse over 22^{+0} weeks of gestation). ✓

Where the woman survives, a consultant intensivist should be involved as soon as possible. ✓

If the maternity unit is an integral part of a general hospital, the maternal CPR team should be the hospital cardiopulmonary arrest team with the addition of:

- senior midwife
- most senior resident obstetrician (usually ST 3–7)
- resident anaesthetist who has recognised skills in obstetric anaesthesia (usually ST 3–7).

This will mean that the request needs to be specific with common terminology, so that the switchboard operators know exactly who to call. While managing the arrest, there must be dialogue between the team leader, the obstetrician and the obstetric anaesthetist as to how best to manage the pregnant woman.

In stand-alone consultant-led maternity units or those that are geographically distant from the main general hospital, the entire arrest team is often made up of staff from within the maternity unit. In this case, the team is usually made up of senior midwifery staff, operating department practitioners, resident obstetric staff and the resident obstetric anaesthetist.

If a maternal collapse occurs in a stand-alone midwifery unit or homebirth environment, the midwifery staff should provide life support and call a 999 ambulance to transfer the woman to the nearest appropriate environment. Maternity services that include a stand-alone midwifery unit should ensure that there is a written agreement with the ambulance service confirming the emergency status of a 999 call from the midwifery unit.

5. Clinical governance

5.1. Documentation

Accurate documentation is essential in all cases of maternal collapse, whether or not resuscitation is successful. ✓

Poor documentation remains a problem in all aspects of medicine and can have potential clinical and medicolegal consequences.[110] Contemporaneous note keeping is difficult in a resuscitation situation, unless someone is scribing. Those involved should then write full notes as soon as possible after the event.

Evidence level 4

5.2. Incident reporting

All cases of maternal collapse should generate a clinical incident form and the care should be reviewed through the clinical governance process. ✓

All cases of maternal death should be reported to MBRRACE-UK. D

Maternal collapse is a rare and potentially devastating event, and substandard care continues to be highlighted.[2–5] In all cases of maternal collapse, care should be reviewed to ensure individual and organisational learning. Staff and the family should be reassured when care has been optimal.

Evidence level 2+

In view of the significant reduction in maternal mortality over the years, robust population-based data regarding maternal collapse through a national reporting system would render valuable information about management and outcomes.

National reporting and scrutiny of maternal deaths continue to provide valuable information and learning, as do confidential enquiries into severe morbidity.[2]

Evidence level 2+

5.3. *Training*

All generic life support training should consider the adaptation of CPR in pregnant women.

✓

All maternity staff should have annual formal multidisciplinary training in generic life support and the management of maternal collapse.

✓

Life support training improves resuscitation skills.

A

Small group multidisciplinary interactive practical training is recommended to improve the management of maternal collapse.

C

All front-line staff must be aware of the adaptations for CPR in pregnancy. This includes paramedics who will deal with collapse in the community setting and accident and emergency department personnel, as well as staff within a maternity unit.

The RCOG, the Royal College of Midwives and MBRRACE-UK[3] recommend that all staff undergo annual training in obstetric emergencies.

Evidence level 4

Multidisciplinary team training in small groups has been shown to improve outcomes in all medical emergencies and there continues to be a wealth of data to demonstrate that this is particularly the case in obstetric emergencies.[111] Interactive training has been shown to improve teamwork, communication and the confidence of individual clinicians to manage obstetric emergencies and increase the incidence of PMCS.[112,113]

Evidence level 1+

The best method of training remains unclear, although there is evidence to support small group interactive training.[111] Various courses exist[73,114,115] and have been evaluated well by those undertaking them with individuals reporting an improved knowledge and confidence after course attendance.[116] The ideal frequency of training is not clear, but this should occur at least annually for all staff.[117]

Evidence level 2–

5.4. *Debriefing*

Debriefing is recommended for the woman, the family and the staff involved in the event.

✓

Maternal collapse can be associated with post-traumatic stress disorder (for the woman, her family and for staff involved), postnatal depression and tocophobia. Debriefing is an important part of holistic maternity care and should be offered by a competent professional to support the ongoing mental health of all concerned.[115]

Evidence level 4

6. Recommendations for future research

- Investigate the effectiveness of CPR with manual uterine displacement versus maternal tilt.
- Determine the effectiveness of human factors and emergency simulation training for maternal collapse clinical scenarios.
- Investigate the best diagnostic and management strategies for AFE.

7. Auditable topics

- Proportion of staff undergoing regular training in life support (100%).
- Proportion of staff undergoing regular training in maternal collapse (100%).
- Audit of the management of maternal collapse (100%).
- Compliance with incident reporting (100%).
- Achievement of PMCS within 5 minutes of collapse on hospital premises, where there is no response to resuscitation (100% in pregnancies over 20 weeks of gestation).
- Presence of a scalpel on resuscitation trolleys (100%).

8. Useful links and support groups

- UK Obstetric Surveillance System (UKOSS) [https://www.npeu.ox.ac.uk/ukoss].
- MBRRACE-UK: Mothers and Babies: Reducing Risk through Audits and Confidential Enquiries across the UK [https://www.npeu.ox.ac.uk/mbrrace-uk].
- Advance Life Support in Obstetrics (ALSO) [http://www.also-uk.com/].
- Practical Obstetric Multi-Professional Training (PROMPT) [http://www.promptmaternity.org/].
- Managing Medical and Obstetric Emergencies and Trauma (mMOET), Advanced Life Support Group (ALSG) [http://www.alsg.org/home/].
- The Birth Trauma Association [http://www.birthtraumaassociation.org.uk/].

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.
Appendix S1. Maternal Collapse literature search strategy

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Appendix 1: Explanation of guidelines and evidence levels

Clinical guidelines are: 'systematically developed statements which assist clinicians and patients in making decisions about appropriate treatment for specific conditions'. Each guideline is systematically developed using a standardised methodology. Exact details of this process can be found in Clinical Governance Advice No.1 *Development of RCOG Green-top Guidelines* (available on the RCOG website at http://www.rcog.org.uk/green-top-development). These recommendations are not intended to dictate an exclusive course of management or treatment. They must be evaluated with reference to individual patient needs, resources and limitations unique to the institution and variations in local populations. It is hoped that this process of local ownership will help to incorporate these guidelines into routine practice. Attention is drawn to areas of clinical uncertainty where further research may be indicated.

The evidence used in this guideline was graded using the scheme below and the recommendations formulated in a similar fashion with a standardised grading scheme.

Classification of evidence levels

1 + +	High-quality meta-analyses, systematic reviews of randomised controlled trials or randomised controlled trials with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews of randomised controlled trials or randomised controlled trials with a low risk of bias
1–	Meta-analyses, systematic reviews of randomised controlled trials or randomised controlled trials with a high risk of bias
2 + +	High-quality systematic reviews of case–control or cohort studies or high-qualitycase–control or cohort studies with a very low risk of confounding, bias or chance and ahigh probability that the relationship is causal
2+	Well-conducted case–control or cohort studies with a low risk of confounding, bias or chanceand a moderate probability that the relationship is causal
2–	Case–control or cohort studies with a high risk of confounding, bias or chance and asignificant risk that the relationship is not causal
3	Non-analytical studies, e.g. case reports, case series
4	Expert opinion

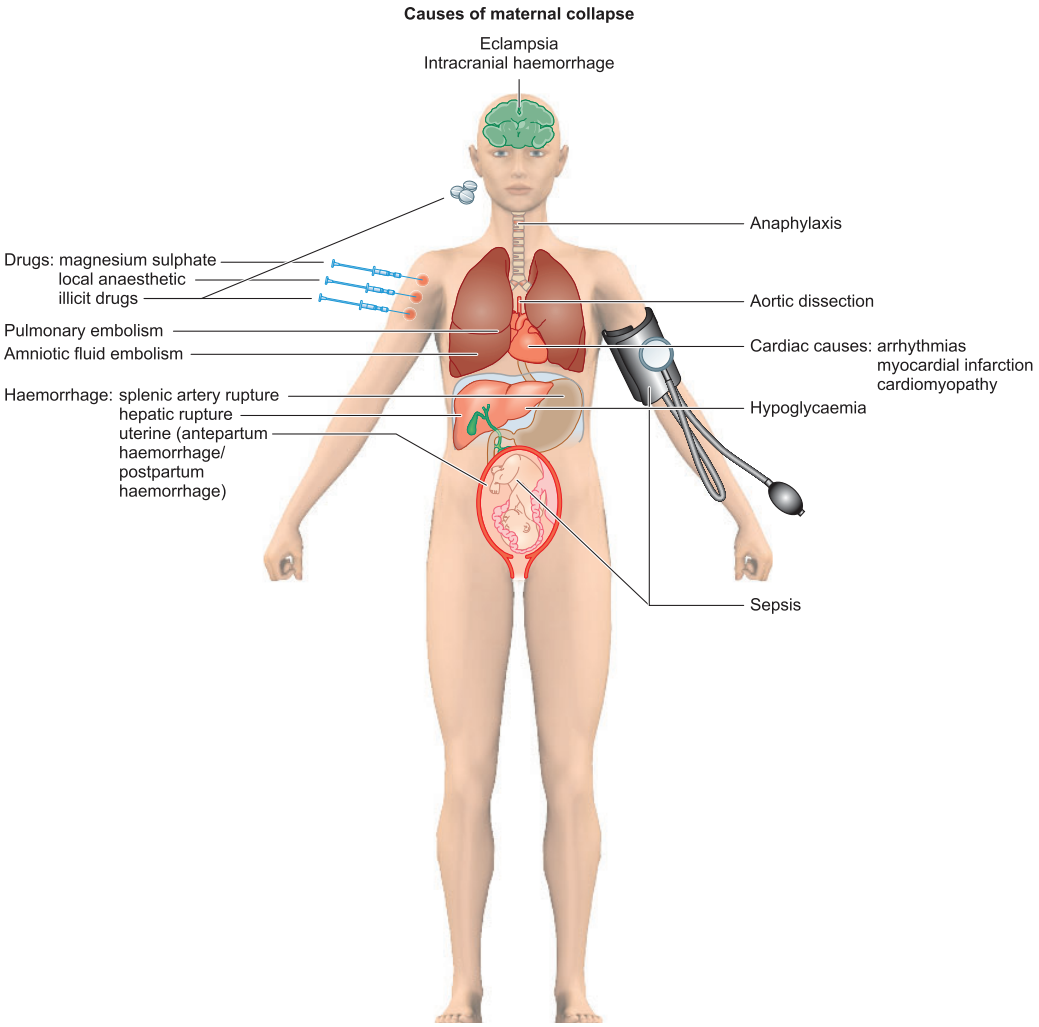
Grades of Recommendation

A	At least one meta-analysis, systematic reviews or RCT rated as 1 + +, and directly applicable to the target population; or a systematic review of RCTs or a body of evidence consisting principally of studies rated as 1 + , directly applicable to the target population and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++ directly applicable to the target population, and demonstrating overall consistency of results; orExtrapolated evidence from studies rated as 1++ or 1 +
C	A body of evidence including studies rated as 2+ directly applicable to the target population, and demonstrating overall consistency of results; orExtrapolated evidence from studies rated as 2 + +
D	Evidence level 3 or 4; orExtrapolated evidence from studies rated as 2+

Good Practice Points

✓	Recommended best practice based on the clinical experience of the guideline development group

Appendix 2: Causes of maternal collapse



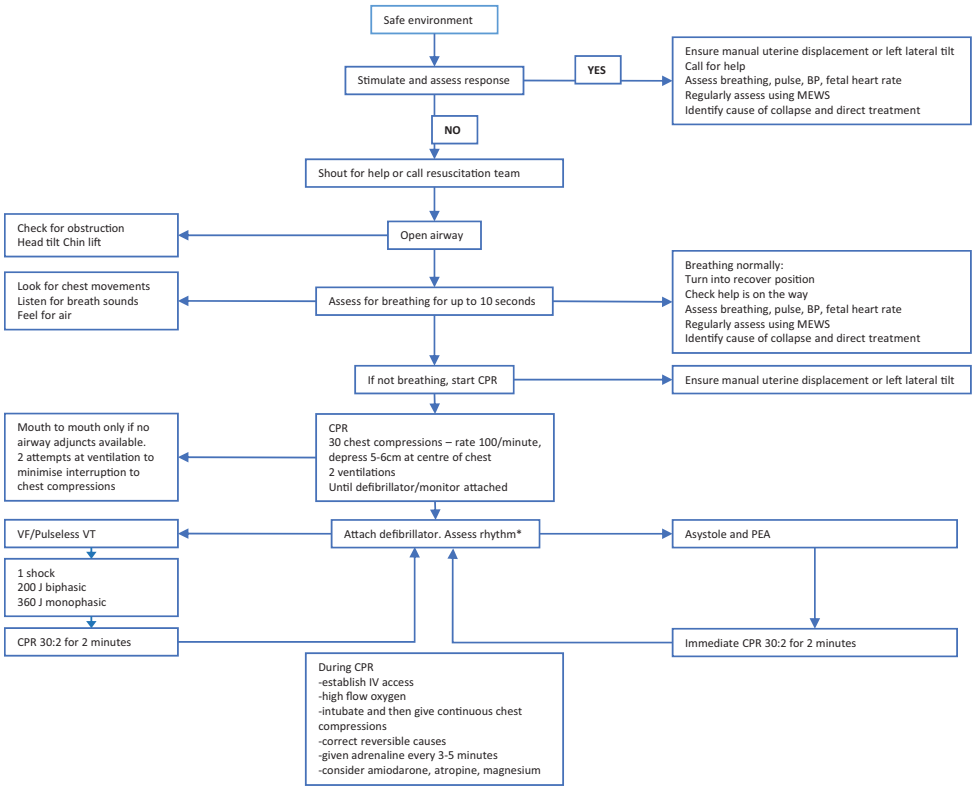
Reversible cause		Cause in pregnancy
4H's	Hypovolaemia	Bleeding (obstetric/other; may be concealed) or relative hypovolaemia of dense spinal block, septic or neurogenic block
	Hypoxia	Pregnant women can become hypoxic more quickly. Cardiac events – peripartum cardiomyopathy, myocardial infarction, aortic dissection, large vessel aneurysms
	Hypo/hyperkalaemia and Hyponatraemia	Hypo and hyperkalaemia are no more likely. Hyponatraemia may be caused by oxytocin use
	Hypothermia	No more likely
4T's	Thromboembolism	Amniotic fluid embolus, pulmonary embolus, air embolus, myocardial infarction
	Toxicity	Local anaesthetic, magnesium, other
	Tension pneumothorax	Following trauma/suicide attempts
	Tamponade	Following trauma/suicide attempts
Eclampsia and pre-eclampsia		Includes intracranial haemorrhage

Appendix 3: Physiological and physical changes in pregnancy

System	Changes in pregnancy	Impact on resuscitation
Cardiovascular system		
Plasma Volume	Increased by up to 50%	Dilutional anaemia Reduced oxygen carrying capacity
Heart rate	Increased by 15–20 bpm	Increased CPR circulation demands
Cardiac output	Increased by 40% Significantly reduced by pressure of gravid uterus on IVC	Increased CPR circulation demands
Uterine blood flow	10% of cardiac output at term	Potential for rapid massive haemorrhage
Systemic vascular resistance	Decreased	Sequesters blood during CPR
Arterial blood pressure	Decreased by 10–15 mmHg	Decreased reserve
Venous return	Decreased by pressure of gravid uterus on IVC	Increased CPR circulation demands Decreased reserve
Respiratory system		
Respiratory rate	Increased	Decreased buffering capacity, acidosis more likely
Oxygen consumption	Increased by 20%	Hypoxia develops more quickly
Residual capacity	Decreased by 25%	Hypoxia develops more quickly when apnoeic
Arterial pCO_2	Decreased	Decreased buffering capacity, acidosis more likely
Laryngeal oedema	Increased	Difficult intubation
Other changes		
Gastric motility	Decreased	Increased risk of aspiration
Lower oesophageal sphincter	Relaxed	Increased risk of aspiration
Uterus	Enlarged	Diaphragmatic splinting reduces residual capacity and makes ventilation more difficult Aortocaval compression causes supine hypotension, reduces venous return and significantly impairs CPR
Weight	Increases	Large breasts may interfere with intubation, makes ventilation more difficult

CPR cardiopulmonary resuscitation; IVC inferior venous cava.

Appendix 4: Maternal collapse algorithm



Correct reversible causes (THE)		
4 Ts Thromboembolism (pulmonary and amniotic fluid Toxic and therapeutic (local anaesthetic) Cardiac tamponade Tension pneumothorax	4 Hs Hypoxia Hypovolaemia Hyper/hypokalaemia (metabolic) Hypothermia	E Eclampsia

***Could be with automated external defibrillator**
Manual uterine displacement (or left lateral tilt)
Empty the uterus if approx. 20 weeks onwards. Aim for uterine evacuation within 5 minutes

Appendix 5: Recommended airway equipment

Routine airway equipment

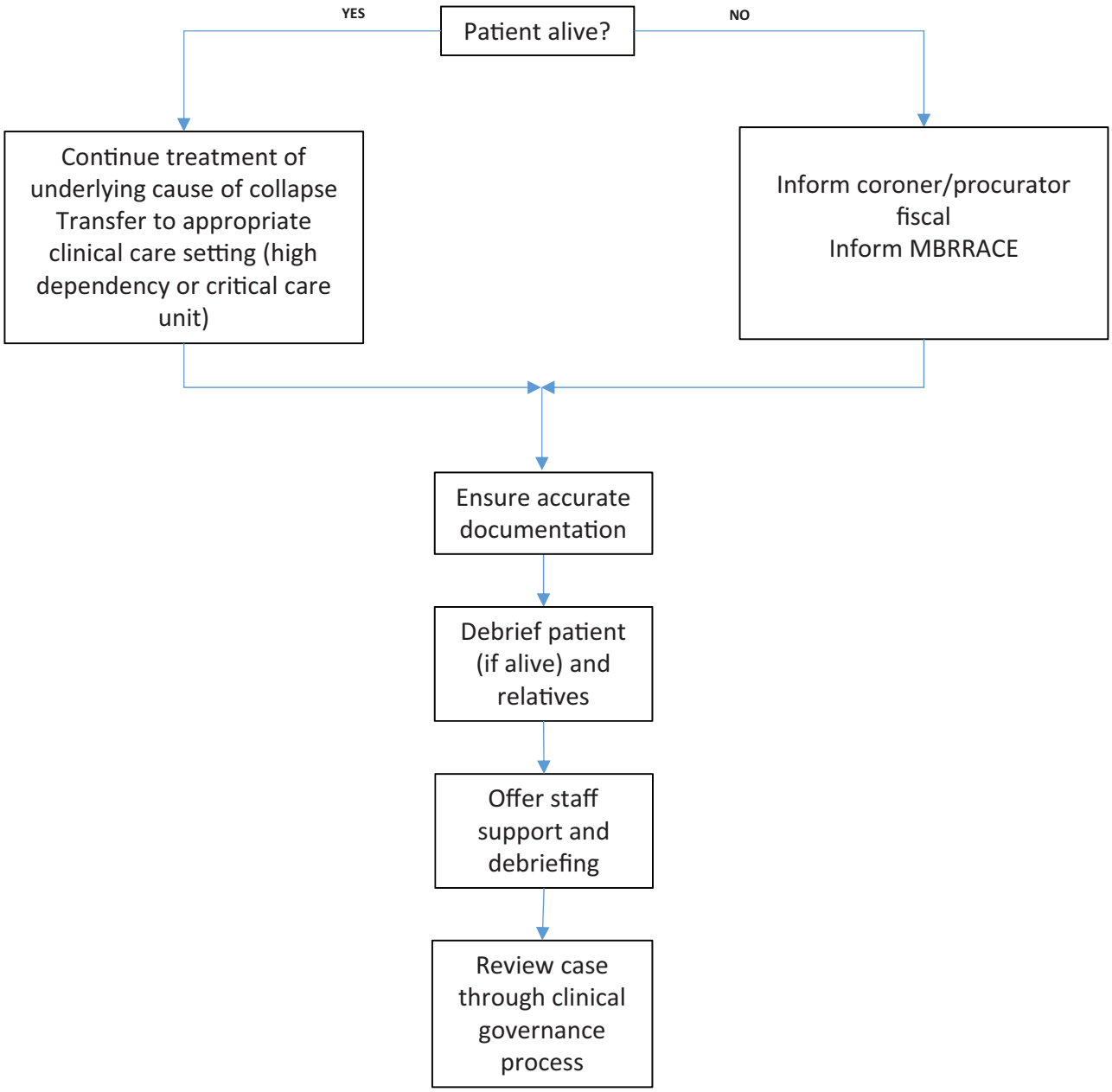
- Face masks
- Oropharyngeal airways size 2, 3 and 4
- Endotracheal tubes in a range of sizes
- Laryngoscopes – Macintosh blades (sizes 3 and 4)
  - two working short handles
  - McCoy laryngoscopes (sizes 3 and 4 blades)
  - videolaryngoscopes (at least one type)
- Tracheal tube introducer – such as a bougie
- Malleable stylet
- Magill forceps
- Nasal cannula and oxygen tubing
- Equipment for ramping/pillows
- Monitoring equipment includin g capnography (see AAGBI guidelines- Recommendations for standards of monitoring during anaesthesia and recovery. 4th edition, 2007)

Recommended equipment for the management of unanticipated difficult intubation

- Endotracheal tubes – range of reinforced tubes, microlaryngeal tubes sizes 5.0 and 6.0 mm, LMA-Fastrach™ tracheal tubes
- Supraglottic airway devices (SAD) to include cLMA, and a second generation SAD (e.g. LMA Proseal™, LMA Supreme™ or I-gel®) - sizes 3, 4 and 5
- LMA cuff pressure manometer
- Fibreoptic scope, camera and monitor
- Aintree® intubating catheter
- Surgical cricothyroidotomy equipment for the 'can't intubate can't oxygenate' situation:
  - Scalpel with No. 10 blade
  - Bougie
  - Size 6.0 endotracheal tube
  - Tracheal hook
  - Forceps or tracheal dilator
- Equipment for awake fibreoptic intubation:
  - Equipment to deliver topical atomised local anaesthetic to the upper airway such as the Mucosal Atomization Device (MAD®) or Mackenzie technique set
  - Berman airway
  - Epidural catheter
  - Local anesthetic for topical anaesthesia (4% lidocaine, Instillagel®)
  - Vasoconstrictors for the nose – phenylephrine/lidocaine (Co-phenylcaine®) or Xylometazoline

Taken from the Obstetric Anaesthetists' Association and Difficult Airway Society [http://www.oaa-anaes.ac.uk/assets/_managed/cms/files/03102015_Equipment_List%20final.docx].

Appendix 6: Post collapse management



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The final version is the responsibility of the Guidelines Committee of the RCOG.

The guideline will be considered for update 3 years after publication, with an intermediate assessment of the need to update 2 years after publication.

