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ESSENTIAL NOTES

Cardiopulmonary resuscitation in the pregnant patient

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Introduction

Maternal cardiac arrest is a rare event, with an incidence of one in 12,000–36,000 women per year in the developed world.[1] A prompt, coordinated response by a multidisciplinary team of anaesthetists, obstetricians, neonatologists and nurses is essential.[2,3] This article reviews the common aetiologies and the organised response that affords the best chance of maternal and neonatal survival – advanced cardiac life support, resuscitative hysterotomy, and treatment of the underlying aetiology.

Aetiology of cardiac arrest and maternal mortality

The rates and common aetiologies of maternal mortality significantly differ between different parts of the world.[4] Although pre-existing disease, cardiovascular disease, cardiomyopathies, infection, and haemorrhage predominate as causes of maternal mortality in settings with well-resourced healthcare, the majority of maternal mortality in resource-poor areas results from haemorrhage.[4,5] Failure to rescue patients in cardiac arrest caused by haemorrhage and hypovolaemia in resource-poor areas is an urgent problem, which is beyond the scope of this review.

In 2015, the overall maternal mortality was nine per 100,000 in the UK and 14 per 100,000 in the USA.[4] According to the World Health Organization, in 2017 the maternal mortality rate was 462 per 100,000 live births in low-income countries. Of all pregnant women in the UK who received basic life support between July 2011 and June 2014, the survival rate was 58%.[3] Coordinated resuscitative efforts, including resuscitative hysterotomy, yield a good chance of survival when the cause of cardiac arrest is a complication related to anaesthesia (e.g. hypoxia, cardiac causes, anaphylaxis, and drug toxicity).[3] Survival is lower when cardiac arrest results from hypovolaemia, venous thromboembolism, sepsis, amniotic fluid embolism, intracerebral bleed, aortic dissection, asthma, and pulmonary artery rupture.[3]

Twenty-five percent of the cardiac arrests in the UK were related to anaesthesia (problem with tracheal intubation, cardiovascular collapse after epidural top-up, total spinal anaesthetic) with obesity complicating the majority of these cases. The predominant causes of maternal arrest in the USA are haemorrhage, heart failure, amniotic fluid embolism and sepsis.[2] Stillbirth, Caesarean delivery, severe pre-eclampsia and placenta praevia are the obstetric issues associated with maternal arrest.[2] Racial disparities in the USA and UK may be a contributing factor, indicated by an approximately three times higher mortality among black than white women in both nations.[2,5] Aetiologies of maternal cardiac arrest with specific treatments are presented in Table 1.

Implications of pregnancy for cardiopulmonary resuscitation

Figure 1 summarises the actions that should take place when maternal cardiac arrest occurs.

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Table 1 Differential diagnosis of maternal cardiac arrest and suggested management. ECMO, extracorporeal membrane oxygenation; HELLP, haemolysis, elevated liver enzymes, low platelet count

Diagnosis		Action item	
Complications of anaesthesia	High neuraxial block	Treat hypotension aggressively (e.g. low dose adrenaline [epinephrine])	
		Support airway and breathing	
	Loss of airway, aspiration, respiratory depression	Support airway and breathing	
		Difficult airway algorithm	
	Hypotension	Treat with vasopressors	
		Lower head of bed to improve cerebral perfusion	
		Volume replacement	
		Obtain more intravenous access	
	Systemic toxicity from local anaesthetics	Give intralipid	
		Consider cardiopulmonary bypass or ECMO	
Bleeding	Coagulopathy	Fibrinogen replacement	
		Fresh frozen plasma	
		Cryoprecipitate	
		Platelets	
		Consider tranexamic acid 1 g i.v.	
	Uterine atony	Give uterotonics	
		Bakri balloon	
		Compression suture	
		Uterine artery embolisation	
		Hysterectomy	
	Placenta accreta	Consider uterine artery embolisation	
		Consider hysterectomy	
	Placental abruption	Delivery if indicated	
		Monitor for coagulopathy	
	Placenta praevia	Delivery if indicated	
		Prepare for lower uterine segment atony	
	Uterine rupture	Uterine repair or hysterectomy	
	Trauma	Call general surgeon	
		Activate massive transfusion	
	Transfusion reaction	Stop transfusion	
		Notify blood bank	
		Adrenaline	
		Steroids	
		Send tryptase	
Cardiovascular	Cardiomyopathy	Inotrope infusion	
		Call for ECMO	
	Myocardial infarction	Inotrope infusion	
		Call for ECMO	
		Call for cardiac surgeon	
		Call cardiac catheterisation laboratory	
		Send cardiac enzymes	
	Aortic dissection	Call cardiac surgeon	
		Activate massive transfusion	
	Arrhythmias	Ventricular fibrillation	Defibrillate
		Unstable ventricular tachycardia (VT)	Amiodarone
			Lidocaine

(*continued on next page*)

Table 1 (*continued*)

Diagnosis		Action item	
		Torsade de pointes	Defibrillate Magnesium
		Stable VT	Amiodarone Lidocaine
		Supraventricular tachycardia	Adenosine
		Atrial fibrillation	Amiodarone Cardioversion
Drugs	Anaphylaxis	Adrenaline Steroids Diphenhydramine Ranitidine	
	Illicit	Opioid overdose	Naloxone
		Benzodiazepine overdose	Flumazenil
		Cocaine coronary vasospasm	Oxygen, aspirin, nitrates, thrombolytic therapy, or acute percutaneous coronary intervention
	Drug error	Identify, discontinue agent and treat	
	Magnesium toxicity	Stop magnesium Give calcium chloride 10 ml in 10% solution or calcium gluconate 30 ml in 10% solution	
	Insulin overdose	Give glucose/dextrose Glucagon	
	Oxytocin overdose	Treat hypotension	
Embolic	Pulmonary embolus	Call Interventional radiology Call cardiac surgeon Prepare catheterisation laboratory Echocardiography Start heparin i.v. Consider thrombolytics in cardiac arrest Nitric oxide	
	Coronary thrombus	Call cardiac surgeon Catheterisation laboratory Nitroglycerine Nitric oxide if right heart failure	
	Amniotic fluid embolism/Anaphylactoid syndrome of pregnancy	Adrenaline Initiate cardiopulmonary resuscitation Call for extracorporeal membrane oxygenator Call for transoesophageal echocardiography Prepare for coagulopathy and need for massive transfusion protocol Consider unproven 'A-OK' therapy: atropine, ondansetron, ketorolac Consider steroids Consider nitric oxide	
	Air	Flood field if uterine venous sinuses open Internalise uterus	
Fever	Infection, sepsis	Give broad spectrum antibiotics Fluids, volume replacement Vasopressors Place arterial line Perform echocardiogram Inotrope if low cardiac output	

General non-obstetric causes of cardiac arrest	Hypotension	Treat with vasopressors Lower head of bed to improve cerebral perfusion Fluids, volume replacement Obtain more intravenous access Call for transthoracic echocardiography
	Hypoxia	Airway control 100% oxygen
	Hypothermia	Warm patient Warm fluids Blankets Increase room temperature
	Hyperkalaemia	Calcium Insulin and glucose Furosemide Albuterol Sodium bicarbonate to correct acidosis Intubate and hyperventilate Polystyrene sulphonate (potassium binder) Consider haemodialysis
	Hypoglycaemia	Give glucose/dextrose Glucagon
	Hypercarbia/acidosis	Intubate trachea and optimise ventilation Determine cause of acidosis Sodium bicarbonate
	Thrombus	See pulmonary embolus above
	Trauma	Call general or trauma surgeon
	Toxin	Give antidote if agent known
	Tension pneumothorax	Needle decompression Insert chest tube
	Tamponade	Call for ECMO Call cardiac surgeon
Hypertension	Pre-eclampsia/eclampsia/HELLP	Antihypertensive agents: labetalol (avoid in asthmatics), hydralazine, nicardipine Magnesium
	Intracranial haemorrhage with increased intracranial pressure	Call neurosurgeon BP goal: systolic <140 mmHg Elevate head of bed 30° Reverse coagulopathy if present Hypertonic saline/mannitol

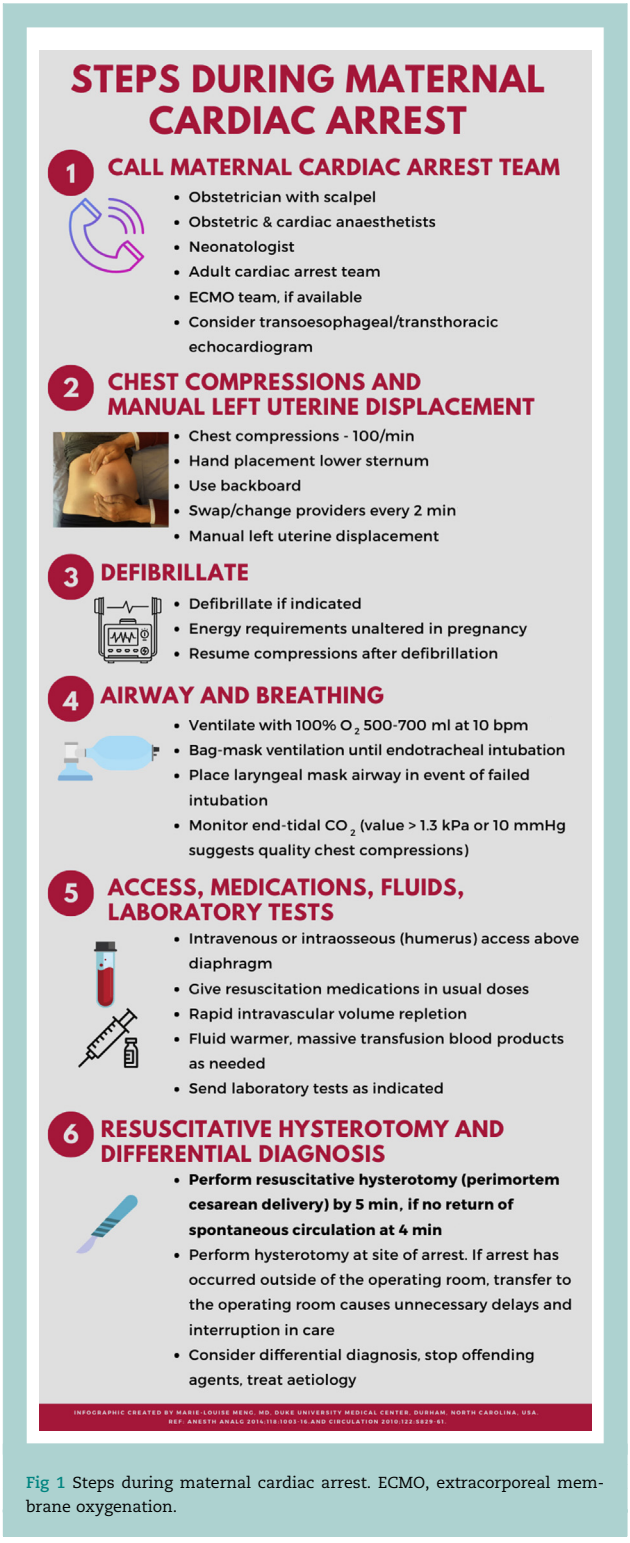

Fig 1 Steps during maternal cardiac arrest. ECMO, extracorporeal membrane oxygenation.

Chest compressions

Chest compressions should be hard and fast, performed on a firm flat surface – achieving at least 5 cm depth and at a rate of 100 compressions min^{-1}. A backboard may be required if resuscitation is taking place on a typical hospital mattress. The optimal hand position during chest compression is the lower sternum.[6,7] There is no scientific evidence to support a higher hand position on the sternum, despite the fact that the gravid uterus may cause superior and anterolateral displacement of the myocardium. When possible, transoesophageal guidance can be used to confirm adequate compression location.

Left uterine displacement

The enlarging gravid uterus impairs resuscitative efforts because of reduced venous return secondary to obstruction of the vena cava in the supine position, beginning at 20 weeks' gestation. Gestational age ≥20 weeks can be assumed if the fundus reaches or exceeds the level of the umbilicus. To prevent decreases in preload, left uterine displacement must be performed during resuscitation. Manual left uterine displacement is preferred over left lateral tilt as it is more difficult to create the appropriate compression force vector when left lateral tilt is used. Manual left uterine displacement can be performed from the left side of the patient, using two hands to pull the uterus upward and to the left or from the right side of the patient by pushing the uterus up and to the left.[6]

Airway and ventilation

Decreases in functional residual capacity and increased oxygen consumption by the fetus lead to rapid development of hypoxaemia. Vascular engorgement results in oedema of the oro- and nasopharynx, larynx and trachea, and may result in difficult intubation and necessitate smaller tracheal tubes. Videolaryngoscopy has been recommended for the first intubation attempt, if possible, to increase the chances of success. Confirmation of tracheal intubation with a capnometer is advised. Nasopharyngeal airways should be used with caution because of the increased risk of bleeding. Ventilation with 100% oxygen with tidal volumes of 500–700 ml at 10 bpm is recommended.

Intravenous access

Large-bore intravenous access should be obtained above the diaphragm as uterine compression and bleeding may prevent adequate resuscitation from below the diaphragm. Ultrasound-guided venous access or intraosseous access in the proximal humerus may be necessary in cases where access is difficult.

Drugs

During pregnancy, circulating blood volume increases out of proportion to the increase in haemoglobin, creating a physiologic anaemia. Increased blood volume and decreased protein binding may theoretically mildly alter the volume of distribution of administered drugs, but these changes are negligible in the low flow state of arrest. Drugs of resuscitation should be administered according to standard guidelines, with none considered to be contraindicated.[6] Oxytocin should be discontinued because of its vasodilatory and negative inotropic effects. Neuraxial local anaesthetic infusions should also be discontinued. Magnesium should be discontinued if it is contributing to significant hypotension.

Defibrillation

Defibrillation should be performed for a shockable rhythm and is considered to be safe for the fetus during maternal cardiac arrest. No changes to the energy requirements are necessary with unchanged thoracic impedance in pregnancy. The theoretical risk of burns from fetal external and internal monitors should not delay the initiation of defibrillation because of waiting to disconnect or remove from the mother.

Perimortem Caesarean delivery/resuscitative hysterotomy

Maternal and neonatal survival are improved when the time from arrest to resuscitative hysterotomy is less than 5 min *vs* greater than 5 min—61% *vs* 35% for the mother and 96% *vs* 70%, for the neonate.[3] Removing the fetus reduces oxygen consumption and removes the anatomical barrier to vena cava flow and optimal pulmonary mechanics. Importantly, maternal survival is also higher (72% *vs* 36%) when resuscitative hysterotomy is performed at the site of arrest instead of transfer to the operating theatre.[3] Equipment necessary for Caesarean delivery (especially a scalpel) should be immediately available.

Team preparedness

Because this is a high-stakes/low-frequency event, maternal cardiac arrest response plans and plans to mobilise responders should be regularly reviewed by obstetricians, anaesthesiologists, neonatologists and labour and delivery nurses, with didactic and simulation sessions. It has been demonstrated in a simulated setting that *in situ* drills reduce the time to initiation of cardiopulmonary resuscitation (CPR) and resuscitative hysterotomy.[8]

Strong leadership and teamwork are essential. Team members should use closed-loop communication, acknowledging tasks assigned by the leader, announcing when the tasks have been completed, and should feel empowered to make suggestions to improve care. These situations are often hectic, and the leader should provide direction and strive to maintain team organisation. Once enough support arrives, the code leader should be in a position of oversight to ensure completion of tasks, identify the differential diagnosis and appropriate treatment.

Transoesophageal echocardiography

Where the equipment and expertise are available, transoesophageal echocardiography may be used to identify the cause of arrest and to assess the efficacy of the resuscitative efforts. It may help identify the presence or absence of gross pathology (spontaneous coronary artery dissection with wall motion abnormalities, aortic dissection, pericardial and pleural effusions, saddle pulmonary embolism, ventricular thrombus etc.) and may aid placement of the cannulae for extracorporeal membrane oxygenation (ECMO) cannulation. Echocardiography can also help assess the efficacy of chest compressions as the location of compression vector and return of myocardial function can be visualised. Acquisition of transthoracic or subcostal images is limited during resuscitation.

ECMO CPR

ECMO has been used to stabilise critically ill obstetric patients and extracorporeal CPR (ECPR) and used as rescue therapy in maternal cardiac arrest attributable to cardiopulmonary causes.[9,10] Although there are few absolute contraindications in obstetric patients, caution is warranted in patients with massive haemorrhage or disseminated intravascular coagulopathy as extracorporeal circulation may activate coagulation factors and worsen thrombosis or coagulopathy. Obstetric patients at high risk of cardiopulmonary decompensation should be managed at hospitals with ECMO capabilities.

Return of spontaneous circulation

Usual post-resuscitation care should occur when return of spontaneous circulation is achieved. Patients may require further surgery to repair or close the resuscitative hysterotomy. Appropriate haemostasis, antibiotics and intensive care protocols should be followed including hypothermia where appropriate. Maternal hypothermia may worsen coagulopathy. Patients with return of awareness will require appropriate analgesia and sedation.[6]

Conclusions

In the rare occurrence of maternal cardiac arrest, prompt initiation of CPR, effective left uterine displacement, coordination of multidisciplinary provider response, early use of ECMO when available and appropriate, and early resuscitative hysterotomy improve both maternal and fetal survival. The addition of transoesophageal echocardiography may aid early recognition of the aetiology of cardiac arrest and assessment of the effectiveness of resuscitation.

Declaration of interests

The authors declare that they have no conflicts of interest.

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