Perimortem caesarean section

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ABSTRACT

This review describes a simple approach to perimortem caesarean section (PMCS) that can be used by a doctor in the resuscitation room or prehospital environment when faced with a mother of more than 20 weeks gestation in cardiac arrest. It explores the indications for and contraindications to the procedure, the physiological rationale behind it, equipment needed, technical aspects of the procedure and reviews recent literature on maternal and fetal outcomes. Like other uncommon procedures such as emergency department thoracotomy, rehearsal and preparation for a PMCS is essential to give both mother and baby the best chance of survival.

INTRODUCTION

Few things are more stressful to an emergency physician than being faced with a pregnant woman in cardiac arrest. A perimortem caesarean section (PMCS) could save her life, and the life of her baby, when performed in the right circumstances.[1–4] Emergency physicians should have the knowledge required to undertake the procedure without an obstetrician present, should the need arise. Deficits in knowledge and anxieties around the procedure are common.

This review describes a simple approach to PMCS that can be used by a doctor in the resuscitation room or a prehospital environment when faced with a mother of more than 20 weeks gestation in cardiac arrest. It explores the indications for and contraindications to the procedure, the physiological rationale behind it, equipment needed, technical aspects of the procedure and reviews recent literature on maternal and fetal outcomes. Like other uncommon procedures such as emergency department thoracotomy, rehearsal and preparation for a PMCS is essential to give both mother and baby the best chance of survival.

Maternal cardiac arrest is a rare event occurring in approximately 1 in 30 000 pregnancies.[5] Outcome will depend on prompt decision-making and effective resuscitation. The primary purpose of a PMCS is to improve the chances of the mother's survival, and this should remain the focus at all times. It should be considered in cases of maternal cardiac arrest after 20 weeks gestation[1–3] (or in women with an 'obviously gravid uterus'),[4] irrespective of fetal condition, if conventional measures have failed to achieve return of spontaneous circulation (ROSC) within a short timeframe. Fetal survival becomes possible at around 24 weeks gestation.

MATERNAL CARDIAC ARREST

The cause for maternal cardiac arrest may be related to pregnancy, or may be non-pregnancy related and may be traumatic or non-traumatic.

In non-traumatic cardiac arrests, advanced life support (ALS) guidelines should be followed.[2–4] Of the reversible causes of cardiac arrest, thromboembolic, hypoxic and hypovolaemic (haemorrhagic and septic) causes are most likely in the pregnant patient. Intracranial haemorrhage and obstetric causes such as eclampsia and amniotic fluid embolus also need to be considered.

In traumatic cardiac arrests, the pathological mechanism is likely to differ from non-traumatic cardiac arrests, and treatment of the likely reversible causes should be initiated. This may include intubation and ventilation to reverse hypoxia, chest decompression to address possible tension pneumothorax, giving fluids (blood and blood products) to address hypovolaemia, and thoracotomy as indicated. If available, a traumatic cardiac arrest protocol should be followed.[6]

PHYSIOLOGICAL CONSIDERATIONS DURING MATERNAL CARDIAC ARREST

From a gestational age of 20 weeks, the gravid uterus causes aortocaval compression, impeding venous return and cardiac output.[7 8] In non-pregnant women undergoing cardiopulmonary resuscitation (CPR), chest compressions only achieve around 30% of the normal cardiac output.[9 10] In pregnant women with aortocaval compression, this drops to around 10% at best during CPR.[7 11]

As a primary intervention, the uterus should be manually displaced to the patient's left side after 20 weeks gestation (where the top of the uterus is palpable at or above the umbilicus), and 'pulling' has been shown to be better than 'pushing'.[12] The Resuscitation Council (UK) now only recommends left lateral tilt of 15°–30° if the patient is on a dedicated tilting table[2] (as tilting the patient makes the provision of adequate chest compressions more difficult).

Delivery of the fetus and placenta improves venous return and cardiac output, facilitating closed chest compressions, reducing oxygen consumption, making ventilation easier and it can also allow internal cardiac massage by compression of the heart (with the diaphragm still intact) against the anterior chest wall.[1 5 13]

The greater the gestational age, the greater the likely benefit of performing a PMCS. The American Heart Association (AHA) has revised its recommendations on when to perform the procedure from '20 weeks gestation'[3] to mothers with an 'obviously gravid uterus' (a uterus that is deemed clinically to be sufficiently large to cause aortocaval compression).[4] This is more likely to represent a gestational age of 24 weeks or greater.

ESTIMATING GESTATIONAL AGE

Estimates of gestational age are often difficult in the emergency situation. As a general rule, the

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Table 1 Indications and contraindications for PMCS.

Indications	Contraindications
(All the following must apply to proceed with PMCS) ▶ Existing attempts at resuscitation have been unsuccessful at 4 min post maternal cardiac arrest. ▶ Gestation 20–24 weeks or greater (ie, uterine fundus palpable at or above umbilicus). ▶ 'Short' time interval from onset of maternal cardiac arrest (ideally PMCS should be initiated at 4 min and completed by 5 min post arrest, but still consider PMCS even if around 15 min post arrest).	▶ Less than 4 min since maternal cardiac arrest (unless mother has known unsurvivable condition). ▶ ROSC achieved after initial resuscitation measures. ▶ Known gestation less than 20–24 weeks, unless uterine fundus is palpable above the umbilicus (eg, multiple pregnancy). ▶ 'Prolonged' time interval since arrest (eg, >15 min, as outcome is likely to be poor, although fetal survival has been reported up to 30 min post maternal cardiac arrest).

PMCS, perimortem caesarean section; ROSC, return of spontaneous circulation.

uterus reaches the umbilicus at 20 weeks and grows at a rate of approximately 1 cm in length for every week thereafter. One fingerbreadth is roughly 2 cm, and can be used to guide the estimate, for example, a uterus extending four finger breadths above the umbilicus would represent a gestation of 28 weeks. Realistically, ultrasonography is unlikely to be of practical use to determine gestational age in this time-critical setting, although it can be used to confirm pregnancy if there is uncertainty.

TIMING OF PMCS

Pregnant women become hypoxic more quickly than non-pregnant women. Irreversible brain damage can begin in the mother within 4–6 min of cessation of cerebral blood flow.[8–11 14] Current guidelines (2011) from the Royal College of Obstetricians and Gynaecologists (UK) recommend that if ROSC is not achieved after 4 min of resuscitative efforts or if resuscitation is continued beyond this in women beyond 20 weeks of gestation, caesarean delivery should be undertaken to assist maternal resuscitation.[1] Ideally, delivery should be achieved within 5 min of maternal arrest.[1 2] However, positive neonatal and maternal outcomes are still possible well outside this time window.[8 15 16]

If the mother is peri arrest, preparations should be made for anticipated PMCS. This may include bladder catheterisation if it can be achieved rapidly, and application of skin preparation and cleaning. The PMCS should be carried out at the scene of the cardiac arrest, as transporting the mother to the operating theatre, for example, will result in unacceptable delay.

INDICATIONS/CONTRAINDICATIONS FOR PMCS

Indications and contraindications for PMCS in maternal cardiac arrest are shown in table 1.

EQUIPMENT NEEDED

In extremis, a PMCS can be achieved with very limited equipment (a scalpel alone), but in an ideal environment, where preparations have been made for the eventuality, the equipment outlined in table 2 will make the procedure easier and will aid neonatal resuscitation. The procedure should not be delayed if the recommended equipment is not immediately available.

PERSONNEL

Maternal cardiac arrest will require three teams and a team leader to coordinate:

- Resuscitation team for mother;
- Team performing caesarean section;
- Resuscitation team for baby.

The ideal team would include an emergency physician, an obstetrician plus assistant, senior midwife, neonatologist or paediatrician and support nurse, anaesthetist or critical care physician, airway nurse or operating department practitioner, drugs and monitoring nurse, intravenous (IV) access practitioner. An interventional radiologist may be involved subsequently to control postpartum bleeding.

The PMCS itself is best performed by the person with the most surgical experience, preferably an obstetrician, but if this expertise is not immediately available, the task may fall to the emergency physician.

DO I USE A HORIZONTAL OR VERTICAL APPROACH?

Both skin and uterine incisions may be vertical or horizontal. These incisions need not necessarily be in the same plane, for example, a vertical midline skin incision does not mandate a vertical uterine approach, however, keeping to the same plane may reduce cognitive overload. It is generally accepted that the skin incision should be vertical, but evidence is lacking and opinions differ on whether a vertical or horizontal uterine incision should be used. The operator should use the approach they feel will allow the quickest delivery with best access. The choice of approach is unlikely to be critical, but should have been considered and decided upon before you are faced with this scenario in practice. The different approaches with their advantages and disadvantages are explored below.

Skin incision

Vertical midline skin incisions generally allow faster abdominal entry[17] and can easily be extended cephalad if more space is required for access. This approach is aided by the natural

Table 2 Recommended equipment set for PMCS.

Personal protective equipment	Double gloves, face mask, apron or gown.
Caesarean section equipment	Scalpel—preferably large, (eg 20 series). Scissors—blunt ended to minimise injury to fetus. Retractors—an assistant's hands can retract if not available. Clamps/haemostats. Gauze swabs—these should be swabs that show up on X-ray. Suction—(although the patient will experience minimal bleeding until ROSC). Large sutures—absorbable. Needle holder. Antiseptic solution and clean linen/incontinence pads.
Neonatal resuscitation equipment	Dry linen, neonatal Bag Valve Mask, Resuscitaire® or baby-warmer, plastic bag (for use if the baby is premature), neonatal airway supplies, appropriately sized suction, equipment for umbilical venous access, resuscitation drugs.

PMCS, perimortem caesarean section; ROSC, return of spontaneous circulation.

diastasis of the rectus muscles in the midline seen in later pregnancy and will generally allow better visualisation of the uterus when compared with the horizontal approach. A vertical skin incision also facilitates access to the heart to allow internal cardiac massage if required.

Transverse incisions generally result in greater blood loss (noticeable only after ROSC as bleeding is minimal during cardiac arrest) and are more likely to cause nerve injury.[18]

Uterine incision

A horizontal hysterotomy (uterine incision) may favour a faster delivery as the lower uterine segment is thinner, and therefore easier to cut through. The lower uterine segment is generally about 3–5 mm thick at term gestation whereas the upper segment/fundus is about 9 mm.[19 20] Uterine thickness is proportionally greater with earlier gestation. Other advantages of a horizontal approach include the reduced likelihood of bladder injury, and reduced blood loss.

A vertical hysterotomy requires an incision which approaches (and may go into) the thick uterine fundus which can be significantly thicker than that described above. The fundus is spongy and hugely vascular and can constrict quickly after being cut, which may result in the initial incision becoming too small for successful delivery of the head. Smaller body parts are then likely to present first, increasing the chance of an obstructed breech presentation, delaying delivery. The extent of fundal constriction may be limited in a relatively atonic uterus post cardiac arrest.

The major disadvantage of a horizontal approach is that significant lateral extension is not possible without risking laceration of major blood vessels.[18] This becomes a problem where the gestational age is less than about 28 weeks, the lower uterine segment is thick, poorly developed and a horizontal incision cannot be extended laterally enough for successful delivery without undue risk. Where the gestational age is known or estimated to be less than 28 weeks or the uterus looks 'small', a vertical approach is therefore recommended.

PROTOCOL TO FOLLOW IN THE EVENT OF MATERNAL ARREST

See figure 1.

PMCS—HOW TO DO IT

1. Ensure the patient is supine and continue CPR (non-traumatic arrest).
2. Manual uterine displacement to the patient's left should be continued until skin incision.
3. Rapidly apply skin prep (only if this will not cause delay).
4. Skin incision (vertical or horizontal):
   A. *Vertical midline incision (recommended)*: Make a midline incision from the symphysis pubis to the umbilicus. If present, the hyperpigmented linea nigra can be used as a guide for the incision. Cut through the skin, subcutaneous tissue then fascial layer (which is white and shiny) before separating the rectus muscles bluntly down the midline using the clawed fingers of your hands to expose the peritoneum. A vertical incision will generally allow better uterine visualisation when compared with a horizontal incision.
   B. *Horizontal incision*: Make a bikini line incision, two fingerbreadths above the symphysis pubis at least 20 cm in length. Cut through the skin, subcutaneous tissue then fascial layer (which is white and shiny) before separating the rectus muscles bluntly down the midline using the clawed fingers of your hands to expose the peritoneum.
5. Use your hands to pull the peritoneum open (alternatively you can use scalpel or scissors for entry).
6. Use the hands of an assistant to pull the abdominal wall laterally on both sides to expose the uterus.
7. You may see the bladder inferiorly (which looks yellow and is enveloped with fatty tissue). A bladder retractor, if available, may be used to reflect this and therefore protect the bladder while gaining better visualisation of the uterus.
8. Uterine incision (vertical or horizontal):
   A. *Vertical incision*: Make a midline incision starting at the lower end of the uterus, avoiding the bladder inferiorly and extend it upwards towards the thick (usually 9+ mm) uterine fundus with the scalpel, being careful to stay in the midline. Blunt-ended scissors can be used to extend the incision towards the fundus (although this may be technically difficult as the upper segment/fundus is sometimes very thick). The middle and index fingers should be used to lift the uterine wall away from the fetus.
   B. *Horizontal incision*: Make an incision with the scalpel in the thin (usually 3–5 mm) lower uterine segment. The incision should be roughly 15 cm in length. The initial incision can be extended if necessary either using blunt-ended scissors (and your middle and index fingers to lift the uterine wall away from the fetus) or by stretching the uterine tissue with your fingers. Avoid the major uterine blood vessels laterally. (If gestation is less than 28/40, use vertical approach as horizontal incision cannot be extended laterally enough for successful delivery without undue risk).
9. If the placenta is in the way—cut through it.
10. Whether you cut the amniotic membranes, releasing amniotic fluid, does not matter at this stage. Leaving it intact may actually assist delivery. Use your dominant hand to locate the presenting part (head, bottom or feet). It may be necessary to disengage the presenting part from the pelvis.
11. Use your cupped hand to elevate the presenting part through the uterine incision aided by transabdominal pressure applied by the other hand or the hands of an assistant. This manoeuvre will rupture the amniotic sac releasing amniotic fluid. Be careful not to hyperextend the fetal neck.
12. Use traction along with further transabdominal pressure to deliver the rest of the baby.
13. Clamp the cord twice and cut immediately between clamps.
14. Hand the baby to the neonatal resuscitation team.
15. Deliver the placenta by applying traction to the remaining cord or separate manually.
16. Clear the inside of the uterus of remaining debris using a large gauze swab.
17. Massage the uterine fundus to stimulate uterine contraction and lessen further blood loss.
18. Apply clamps to any actively bleeding uterine vessels.
19. Ensure that the bladder is empty (insert Foley catheter if necessary).
20. Give Syntocinon (5 units by slow IV injection):
   A. For *non-traumatic maternal cardiac arrest*, if the mother is still in cardiac arrest after delivery, internal cardiac massage can be performed by compression of the heart (with the diaphragm still intact) against the anterior chest wall. Aortic compression or clamping is

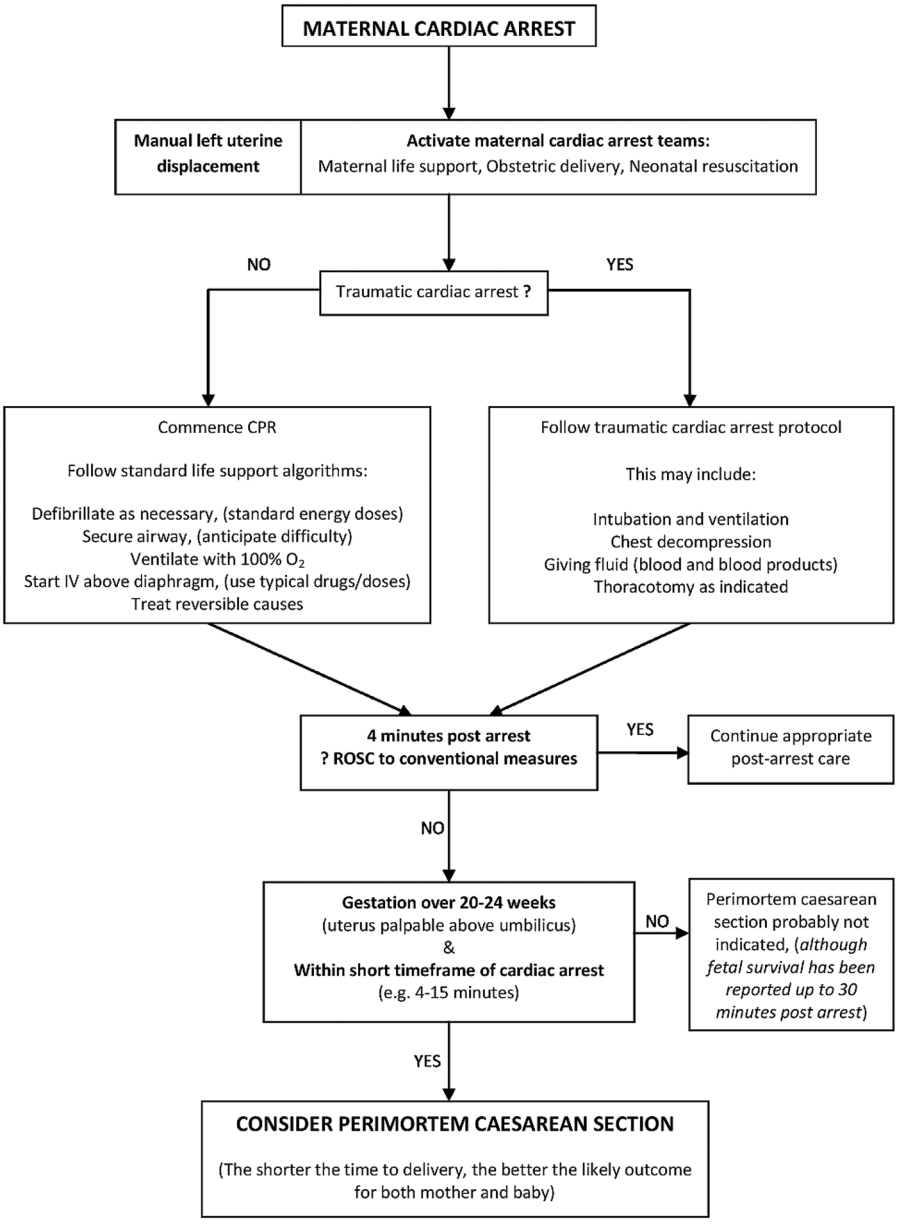

Figure 1 Protocol to follow in the event of maternal arrest.

also possible. If ROSC is not achieved soon after delivery, a number of cycles of CPR should be performed before deciding whether to stop resuscitation.

B. For *traumatic maternal cardiac arrest*, response to treatment should be reviewed after PMCS and a decision regarding ongoing resuscitation can then be made based on the likely aetiology of the traumatic cardiac arrest.

21. Should the mother regain cardiac output, appropriate anaesthesia and sedation may be required.
22. Closure should be based on the mother's response to resuscitative efforts. If ROSC is achieved, a careful layered closure is important to lessen the chance of significant bleeding when normal perfusion returns. If no obstetric help is available to close, temporary packing with large gauze swabs (mobs) may be used and clamps applied to bleeding points until such help arrives. Alternatively, the uterine incision may be closed using large absorbable sutures.
23. Due to hypoxia, the uterus will almost inevitably be atonic and will bleed heavily if ROSC is achieved. Consider giving Ergometrine (0.5 mg by intramuscular (IM) or slow IV injection); repeat dose of Syntocinon (5 units by slow IV injection followed by 40 units of Syntocinon in 500 mL of normal saline by IV infusion over 4 h); Carboprost (0.25 mg every 15 min, max eight doses, by IM injection); Misoprostol (1 g per rectum/per vagina).[21] Give tranexamic acid (1 g IV bolus, then 1 g IV over 8 h). Non-pharmacological measures to help control uterine bleeding include uterine balloon tamponade, ligation of uterine/iliac arteries, selective arterial embolisation (interventional radiology) and hysterectomy.[21]
24. Prophylactic IV antibiotics should be given according to local hospital guidelines.

DISCUSSION

Maternal/fetal survival

It should be emphasised that PMCS is primarily a resuscitative intervention to improve the chances of the mother's survival, but it follows that good maternal resuscitation will optimise the chance of a good fetal outcome.

Morbidity and mortality data on PMCS are scarce and often biased. Case series tends to report positive outcomes, and

reports such as the Confidential Enquires into Maternal Deaths, negative ones.

In one case series of 94 patients who presented between 1980 and 2010, 54% of mothers who underwent PMCS survived to hospital discharge.[16] The procedure was determined to have been beneficial to the mother in 32% of cases and was not considered harmful in any case. The authors concluded that PMCS had led to a clear neonatal survival benefit in 50% of cases, and that there were no cases where the procedure had been deleterious. However, publication bias, recall bias and under-reporting were acknowledged as potential limitations. In another series, 20 of the 38 mothers who underwent PMCS were considered to have potentially reversible causes of cardiac arrest, and 13 survived (a rate of 65% in the salvageable cohort).[8]

Fetal outcome is related to the time from onset of maternal cardiac arrest to delivery and gestational age.

The '4 minute rule' for PMCS was first recommended by Katz *et al* in 1986[11] and subsequently has been adopted by numerous respected bodies including the AHA and the Royal College of Obstetricians and Gynaecologists (UK).

The rule was based on a case series of 61 infants who survived perimortem caesarean delivery. Forty-two were delivered within 5 min and none had neurological sequelae. Of the 15 who were delivered between 6 min and 15 min, only two had neurological sequelae. There were only four survivors after 15 min, three of whom had severe neurological sequelae.

Katz subsequently reviewed the literature from 1985 to 2004 (acknowledging publication bias) and noted very few PMCS were performed within the 4–5 min time window. Despite these delays, positive neonatal and maternal outcomes were still evident. Thirty eight PMCS deliveries resulted in 34 surviving infants (including three sets of twins and one set of triplets).[8] Twenty-one of these infants had no long-standing adverse sequelae. In the cohort of surviving infants, 12 deliveries were carried out within 5 min of maternal arrest (25–42 weeks gestation) resulting in eight normal infants, one infant with retinopathy and hearing loss and three infants where the infant's condition was not reported. However, seven deliveries were carried out *after* 15 min (30–38 weeks gestation) resulting in four normal infants.

The longest reported time interval between maternal cardiac arrest and a PMCS that resulted in the delivery of a child with subsequently normal neurological development is 30 min. The mother had committed suicide by jumping from the fourth floor of the hospital while in labour.[22] The perceived time of maternal cardiac arrest (as determined by loss of central pulses and signs of life) may not always be the same as the time that circulation ceases. In cases such as hypovolaemic traumatic cardiac arrest, or cardiac arrest from antepartum haemorrhage, the mother may actually be enduring a very low cardiac output state when the time of cardiac arrest is (incorrectly) recorded. This phenomenon may have resulted in some of the more prolonged successful resuscitations following PMCS and makes it worth considering a perimortem section well after the 4–5 min time window has elapsed.

Low fetal survival rates are reported in data from the Confidential Enquires into Maternal Deaths. Over a 25-year period, 56 postmortem/perimortem caesarean sections resulted in only six neurologically normal surviving babies (10.7%). Eight more infants were born alive but did not survive the early neonatal period.[23] Similarly, the 2011 triennial report into maternal deaths highlighted the poor outcome of PMCS performed in emergency departments. Of the 17 women who were pronounced dead in emergency departments and had undergone a PMCS, there was only one live birth, five early neonatal deaths and the remaining babies were stillborn.[24] However, it must be emphasised that fetal outcome is likely to be better if the mother survives, and this data only looks at fetal survival in the event of maternal death.

On a positive note, this data does suggest that if the baby survives the early neonatal period, the chances of normal neurological development are good, and this may be of some reassurance to doctors who are worried about delivering a baby who may suffer severe neurological disability in later life.

Gestational maturity is another key factor in fetal survival. The 2011 triennial report into maternal deaths noted that no babies born at less than 28 weeks gestation by PMCS survived, whereas 47% of babies born by PMCS beyond 36 weeks gestation survived.[24]

Another study on maternal and fetal survival after maternal cardiac arrest is currently underway. The UK Obstetric Surveillance System aims to report on the incidence of cardiac arrest and PMCS in pregnancy and the associated outcomes for women and their infants. Interim results show around 60% of mothers who suffered cardiac arrest survived, of which 71% underwent PMCS. Interim fetal survival rates have not yet been released.[25]

Training

The benefits of multidisciplinary training in managing emergencies is well recognised and has been shown to improve patient outcomes.[26] Simulation can be used to practise a PMCS protocol and facilitate team training in technical skills as well as human factors. Simple mannequin models can be adapted with minimal cost and a little ingenuity, as demonstrated in an online video produced by the Washington University School of Medicine, Division of Emergency Medicine.[27] Other searchable online resources include footage of emergency caesarean sections.

Time spent in an obstetric operating theatre is invaluable in getting practical experience of what the tissues actually look like, how thick the uterus is and what size incision you need to deliver the baby through, etc. Mental imagery rehearsal can be used and has been shown to be of value in learning surgical procedures.[28 29]

Consent and litigation

PMCS is performed in an emergency situation and in the best interests of the patient, and therefore consent is not required. No doctor has ever been prosecuted for performing a PMCS, and consensus opinion suggests that legal action against a doctor performing the procedure would be very unlikely to succeed.[15] Legal action has, however, been initiated against doctors (in the USA) for failing to perform a perimortem section.[15]

CONCLUSION

When faced with a mother of 20–24 weeks gestation or greater, who has been in cardiac arrest for more than 4 min, but not a prolonged amount of time (generally less than 15 min), perimortem caesarean section as described above can be a lifesaving procedure for both mother and baby. Emergency physicians should be aware of, and prepared to undertake such a procedure should the need arise.

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