The occasional maternal cardiac arrest

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INTRODUCTION

Cardiac arrest can suddenly afflict expectant mothers under the care of any physician and requires immediate, optimal treatment. Faced with this critical event, even experienced clinicians frequently omit or misapply the applicable consensus-based modifications to Advanced Cardiac Life Support protocols. A practical approach is presented for physicians responding to maternal cardiac arrest, including a discussion of resuscitative caesarean delivery (RCD), also known as perimortem caesarean delivery (PMCD) or resuscitative hysterotomy (RH). Human factors such as hesitation and opposition from other team members must be addressed in improving care delivery, as these can detract from the effective management of maternal cardiac arrest. More broadly, efforts must expand to maintain provider- and hospital-level readiness via a greater emphasis on PMCD in team-based critical event drills and resuscitation courses. Mothers, babies and families struck by maternal cardiac arrest deserve no less than our best and swiftest responses to this frightening but potentially rectifiable catastrophe.

CASE VIGNETTE

**Has been generalized for confidentiality and educational value.*

You are drifting back to sleep during an overnight obstetrics shift when an overhead alarm shatters the early morning silence. "Code Blue – Labour and Delivery". You arrive to find your 28-year-old patient, previously healthy and actively labouring, now unresponsive, cyanotic and pulseless. The nurse exclaims between chest compressions, "She just suddenly clutched her chest and said she couldn't breathe!" The cardiac monitor shows pulseless electrical activity (PEA). Intravenous access is being obtained. The patient's husband, terrified, stands back from the bedside. Two minutes of ischaemia have already elapsed. *How do you respond?*

SOURCES OF INFORMATION

The PubMed database was searched using the terms 'resuscitative hysterotomy', 'perimortem cesarean', 'maternal cardiac arrest' and 'neonatal survival'. For video resources, EMCRIT.org was searched with the term 'perimortem cesarean'. The relevant sections from the 2020 AHA guidelines[1] and a major resuscitation

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reference manual[2] and its citations were also reviewed. The sources deemed most relevant to clinical decision-making, technique, and expected maternal and neonatal outcomes are summarised below.

INCIDENCE AND AETIOLOGIES

While rare, with fewer than about 30 cases annually in Canada,[3] maternal cardiac arrest can nonetheless present a challenge for clinicians caring for expectant mothers in any context. The most common aetiologies of maternal cardiac arrest include haemorrhage, trauma, embolism of amniotic fluid or thrombus, cardiorespiratory disease, drug toxicity, sepsis and pre-eclampsia.[4]

PROCEDURE AND CONSIDERATIONS

Expert-consensus-based departures from standard advanced cardiac life support (ACLS) protocols, while of low evidential quality, appear to improve maternal and neonatal survival[4,5] yet are often omitted, even by experienced professionals.[6] These include the following additional steps that can be summarised by the mnemonic "**Shove, Squeeze, Correct, and Collect to Cut at 4**" [Table 1].

1. **'Shove':** Provide left uterine displacement (LUD). An assistant standing on the patient's left side should pull the uterus towards him/herself as far as necessary to reduce maternal aortocaval compression [**Figure 1**, Team Member #3]; this technique is considered less detractory from effective chest compressions than tilting the entire patient by 30°.[7] If RCD is initiated, this assistant can move instead to the patient's right side and push the uterus towards the patient's left [**Figure 2**].
2. **'Squeeze':** Compress and ventilate the chest without interruption [**Figures 1 and 2**, Team Members #1 and #2] in accordance with high-quality ACLS.
3. **'Correct':** Treat specific correctable causes promptly [**Table 2**]. The peripartum context may bring into play potentially toxic infusions such as magnesium sulphate or epidural bupivacaine. Any infusions that may be contributory to the arrest should be halted, and their antidotes given (respectively for these examples, calcium chloride and lipid emulsion). Suspected tension pneumothorax should be decompressed.
4. **'Collect to Cut at *4*':** Immediately obtain tools and position the team physically and mentally for possible RCD. Although attempting to resuscitate the mother with foetus still *in utero* is the usual initial tactic, evidence increasingly suggests that separating the two parties may improve the chances of both surviving. As soon as this potential is recognised, the wise leader should not only 'collect equipment' by sending an assistant but also mentally 'collect oneself' and verbally orient the team to the possibility of imminent RCD, even if it is not ultimately performed.

RESUSCITATIVE CESAREAN DELIVERY: WHY. WHETHER. WHEN. WHERE. HOW.

The following principles inform decision-making around the 'why,' 'whether,' 'when,' 'where' and 'how' of RCD:

1. **'Why':** RCD may improve maternal and neonatal survival, and is unlikely to be detrimental to the mother. Delivery of the foetus and placenta may re-divert uterine blood into the maternal circulation.[2] A recent review[4] judged 19 of 60 resuscitative caesarean deliveries under consideration 'clearly beneficial' to maternal survival, and none harmful. The AHA opines that "[a mother] cannot be declared 'refractory' to CPR and ACLS unless all interventions have

Table 1: Critical actions in maternal cardiac arrest

Left uterine displacement, chest compressions and ventilations, firm surface
Halt toxic infusions; intravenous access in upper extremity
If arrest cannot be reversed immediately, deliver foetus (usually by RCD), target <5 min (earlier still if injuries/prognosis are *worse*)
Remove foetal/uterine monitors before defibrillation/cardioversion (theoretical risk of injury)
Notify neonatal team
Rehearse critical events regularly; consider point-of-care checklists and 'reader' role

RCD: Resuscitative caesarean delivery

Table 2: Selected rapidly reversible causes to consider in maternal cardiac arrest		
Aetiology	**Possible antecedents/clues**	**Specific treatments (IV), for a typical 70-kg adult**
Local anaesthetic toxicity	Epidural catheter migration into intravascular space, allowing large amounts of bupivacaine or lidocaine into circulation Recent epidural boluses	Stop epidural infusion Lipid emulsion 20% ('Intralipid') Initial bolus 1.5 ml/kg lean body weight (100 ml), then infusion ~0.25 ml/kg/min
Hypomagnesaemia	Preeclampsia treated with magnesium sulphate	Stop magnesium infusion Calcium chloride, 1 g
Hyperkalaemia	Inadvertent administration of IV potassium; renal failure; release of intracellular potassium, e.g. rhabdomyolysis; peaked T-waves on ECG	Calcium chloride, 1 g Sodium bicarbonate, 50 meq Salbutamol, 20 mg in 4 ml saline (nebulized)
Hypoglycaemia	Inadvertent insulin overdose	Stop insulin Glucose, 25 g (=1 ampule $D_{50}W$)
Eclampsia/ preeclampsia	Hypertension, proteinuria, chest pain and/or headache	Magnesium sulphate, 4 g over 3 min
Tension pneumothorax	Blunt or penetrating thoracic trauma	Needle decompression Finger and tube thoracostomy
Ventricular fibrillation	Various	Defibrillation as per ACLS

ECG: Electrocardiogram, ACLS: Advanced Cardiac Life Support, IV: Intravenous

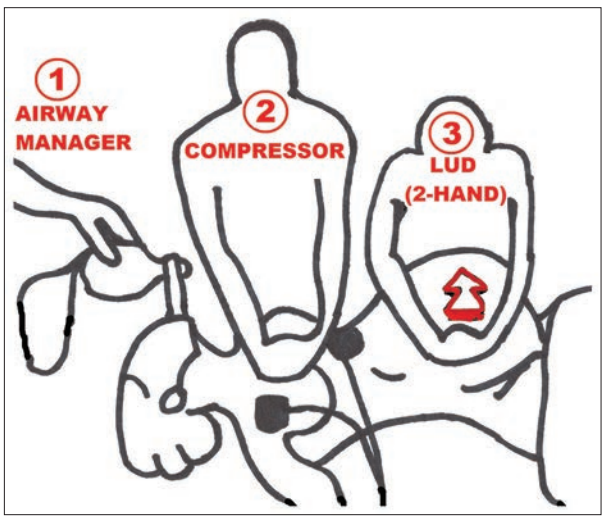


Figure 1: Team position before resuscitative caesarean delivery. LUD = left uterine displacement ('Shove' in mnemonic). Arrow = Team Member #3 pulls uterus towards patient's left flank. Illustrator: E. Chuah.

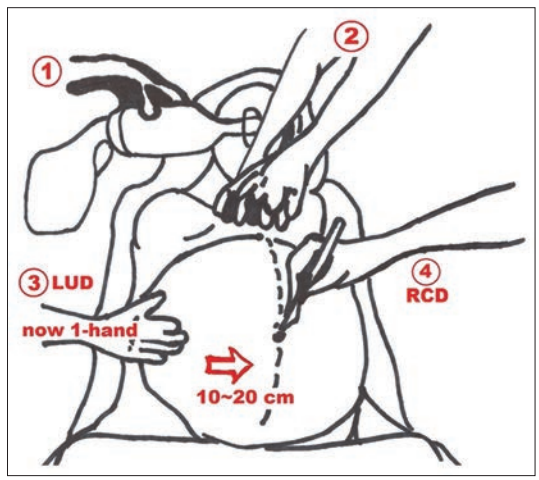


Figure 2: Team position during resuscitative caesarean delivery. Arrow = Team Member #3 pushes ('shoves') uterus towards patient's left flank, while Team Member #4 performs resuscitative caesarean delivery. Illustrator: E. Chuah.

been implemented effectively, including [RCD] when appropriate. No mother should die with a fetus left undelivered when there is aortocaval compression."[2]

2. **'Whether' #1:** Factors *favouring* RCD include aetiologies or circumstances where restoring maternal circulation within approximately 2 to 3 min is doubtful. Resuscitation teams should consider early on whether the aetiology of the arrest is likely to be rapidly reversible. Such aetiologies may include hypoxia, electrically treatable cardiac arrhythmias, tension pneumothorax and certain metabolic disturbances such as hypoglycaemia or hyperkalaemia. The presence of rapidly

reversible causes may argue for keeping one's scalpel holstered; conversely, their absence suggests a need to prepare for likely RCD.

3. **'Whether' #2:** RCD tends to be more beneficial the later the gestational age. Beyond ~ 24 weeks' gestation (roughly the time when the uterine fundus starts to extend above the umbilicus), substantial aortocaval compression and foetal viability grant RCD a higher chance of saving lives than endangering them. A term foetus fully capable of surviving outside gains little from remaining inside an ischemic uterus. Earlier gestations, especially below 20 weeks, present a more difficult dilemma: uterine interference with maternal resuscitation is less pronounced, and the baby is less likely to survive extrauterine life, making RCD less favourable. Mothers carrying 13- to 15-week gestations have been successfully resuscitated without recourse to RCD, eventually delivering at term.[8] Yet if unrecognized aortocaval compression or other pregnancy-related factors impede the mother's resuscitation in early pregnancy, not performing RCD may lead to the loss of both mother and baby, whereas performing it may save the mother's life while sacrificing that of the baby. Although there are no easy answers here, RCD may still be beneficial when no other prospect of reversing the arrest is apparent, to the extent that it may increase the chances of saving at least one life.
4. **'When':** The *less reversible* the aetiology and the *worse* the maternal prognosis, the *earlier* RCD should be done. Maternal and neonatal survival decline rapidly with ongoing ischaemic time, [4,9] and initiation of resuscitative efforts may have already been delayed by several factors common to these scenarios (slow recognition, obstructed access to resuscitation equipment, absent vascular access, interfering patient clothing, etc.); consequently, by the time a physician arrives, the most appropriate time to begin considering RCD is likely 'immediately'. A 2015 AHA Scientific Statement[8] advocates starting the procedure "after about 4 min" from either the onset of cardiac arrest or the start of resuscitative efforts, but emphasises that shorter arrest-to-delivery times are associated with better outcomes. No minimum waiting time is thus required: initiating RCD before the 4-min mark is often appropriate, especially when faced with situations such as "prolonged pulselessness or nonsurvivable maternal trauma, in which maternal resuscitative efforts are obviously futile [...] *there is no reason to delay performing PMCD* (Class I, Level of Evidence C-Limited Data)".[5] Moreover, the procedure itself can easily take more than a minute to perform.[4] RCD should still be performed when indicated even if a longer-than-desirable time has elapsed, as foetal survival has been reported after ischaemic times of 10 or 15 min and longer with high-quality CPR; a defeatist attitude is not appropriate.[4]
5. **'Where':** RCD should be performed 'on the spot'. Moving the mother anywhere is likely to worsen maternal and neonatal outcomes by delaying the return of spontaneous circulation, according to an AHA recommendation (Class IIa, LOE B).[8]
6. **'How':** **Figures 1 and 2** suggest a way to position the team before and during RCD, respectively. The reader is also referred to excellent step-by-step descriptions in major emergency medicine textbooks and online.[10,11] Equipment required is minimal and includes a #10 scalpel and umbilical cord clamp.

Other modifications

Vascular access should be established above the diaphragm to more effectively reach the heart. Endotracheal intubation should be performed by the most experienced provider available, as it may be more difficult in pregnant women. [1,2,8,12] A mechanical device to provide chest compressions may spare limited human resources. Although cardiopulmonary bypass or extracorporeal oxygenation have been proposed, [13] these therapies are unavailable in most settings.

Address 'human factors'

A physician urging RCD in a labour or emergency room may face strong opposition from other members of the healthcare team or the patient's family, for whom performing caesarean delivery in this location may (rightfully) seem brutal, unsterile and highly irregular. Yet because RCD may be vital to successful resuscitation, clinical teams need to prepare and train to mitigate the effect of 'human factors' such as hesitation and

fear as these critical events unfold. Achieving delivery within 5 min of an unexpected cardiac arrest is challenging; only 7% of cases reviewed succeeded.[4] Designating a 'checklist reader' may help speed the team through the required actions.

Rehearse critical events

Resuscitation courses such as ALARM and ACLS and critical-event drills in Canadian hospitals should include 'maternal cardiac arrest events' in their curricula, providing opportunities to rehearse the many actions that need to happen promptly to optimise maternal and neonatal outcomes.

MANAGEMENT OF MATERNAL CARDIAC ARREST: CASE RESOLUTION

You confirm PEA and see no immediate response to left uterine displacement, effective oxygenation and epinephrine 1 mg given in an upper extremity vein. No toxic or traumatic causes are apparent. To mitigate some of the inevitable team hesitation and family distress, you announce, "There's been no pulse for 3 min. We need to do an emergency cesarean delivery right here and now. There's no time to move her anywhere. This is the best way to save the baby, and it could save the mother too. Please get me a #10 scalpel right now."

Chest compressions continue, and the uterus is kept displaced to the left of the great vessels by an assistant using a one-handed technique. A midline incision is made from xiphoid to pubis, the rectus muscles spread, peritoneum entered, and a vertical incision made in the uterus. A nurse, recalling her recent maternal cardiac arrest drill, retracts, evacuates amniotic fluid with suction, and calls an assistant to bring the department's maternal cardiac arrest box.

You lift the vertex cephalad while the nurse applies fundal pressure, delivering a live baby girl. She clamps and cuts the cord and hands the baby to her colleague. By this time, some oozing begins to appear in the previously bloodless surgical field, and the next rhythm check demonstrates a return of spontaneous circulation.

The abdomen is packed with moistened laparotomy sponges until a surgeon arrives. Inotropic and sedative infusions are started to optimise cardiac output and patient comfort as post-resuscitation care continues; intensivist consultation is obtained. Broad-spectrum antibiotics are administered with the aim of preventing a subsequent surgical site infection. Uterotonics are given with due attention to their hemodynamic effects. You debrief the family and team their concerns. The mother and baby go on to make a full recovery from this suspected embolic event.

CONCLUSION

Cardiac arrest in pregnancy continues to challenge clinicians by unexpectedly presenting an extremely time-sensitive condition that immediately endangers two lives and may require bold interventions such as RCD to reverse it. Accumulating evidence supports the above modifications to maximise maternal and neonatal survival. Emphasising maternal cardiac arrest as a special topic in critical event drills and courses may optimise responses to this crisis and save lives. Mothers, babies and families struck by cardiac arrest deserve no less than our best and swiftest responses to this frightening but potentially rectifiable catastrophe.

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