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Perimortem cesarean section for maternal and fetal salvage: concise review and protocol

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Abstract

Cardiopulmonary arrest is a rare event during pregnancy and labor. Perimortem cesarean section has been resorted to as a rare event since ancient times; however, greater awareness regarding this procedure within the medical community has only emerged in the past few decades. Current recommendations for maternal resuscitation include performance of the procedure after five minutes of unsuccessful cardiopulmonary resuscitation. If accomplished in a timely manner, perimortem cesarean section can result in fetal salvage and is also critical for maternal resuscitation. Nevertheless, deficits in knowledge about this procedure are common. We have reviewed publications on perimortem cesarean section and present the most recent evidence on this topic, as well as recommending our "easy-to-access protocol" adapted for resuscitation following maternal collapse.

Abbreviations: CPR, cardiopulmonary resuscitation; CS, cesarean section.

Introduction

Postmortem trans-abdominal delivery was first described in ancient texts originating from the Middle and Far East (1–3). This practice was later coined "cesarean section" (cesarean originates from "*ab matris cesare*" meaning to cut from the mother) when the Roman king Numa Pompilius decreed that burial of a pregnant woman after death was allowable only after the fetus had been removed (715 BC) (4), rather than for maternal or fetal salvage (5–7). The first mention of postmortem cesarean section (CS) in anticipation of fetal rescue was by Bernard of Gordon, a Montpellier physician, in 1305 (8).

As basic understanding of physiology, surgical and anesthetic techniques was lacking until the 19th century, CS performed on living parturients resulted most often in maternal (9) and neonatal death (10,11). In 1986, Katz

Key Message

Perimortem cesarean section is rarely required, but if performed in a timely manner, it may improve maternal and neonatal outcome. Since awareness of this procedure is not universal, training and evidence-based guidelines should be put in place for all obstetric caregivers.

et al. (12) published a seminal article reviewing a series of case reports published between 1875 and 1985 which suggested that early perimortem CS may be beneficial for the fetus and theoretically might obviate the effects of aortocaval compression, hence improving maternal circulation. In that article, it was first suggested that perimortem CS should be initiated within four minutes and the infant be delivered within five minutes of maternal arrest (12). Following this publication, the American Heart Association guidelines in 1992 for cardiac arrest in special situations first endorsed perimortem CS during maternal cardiopulmonary resuscitation (CPR) if there was no evidence of a return of spontaneous circulation (13). Since 1992, the American Heart Association guidelines for perimortem CS have become a standard of care.

Based on assumptions derived from their 1986 landmark series, Katz and colleagues performed a similar review of 38 cases published between 1985 and 2005 (14). This led them to conclude that perimortem CS within four minutes of maternal arrest, which was performed in 11 of the 25 cases where time was known, could improve neonatal outcomes. Furthermore, in 12 of the 18 reports that documented hemodynamic status, perimortem CS might have had a beneficial effect on the mother. The American College of Obstetricians and Gynecologists (15), Royal College of Obstetricians and Gynaecologists (16) and the American Heart Association (17) currently endorse timely extraction of the fetus during ongoing efforts of maternal resuscitation. We herein review the data supporting this practice and suggest an "easy-to-access" protocol for performing the procedure.

Material and methods

A historical and concise review of the literature was done to identify various aspects of perimortem CS with specific focus on its role in maternal and fetal rescue. A Medline search was undertaken of all reports and reviews published between 1980 and 2013 using the terms [MeSH] "pregnancy" AND "perimortem" OR "cardiopulmonary resuscitation" OR "postmortem". The search was not limited to publications in English. Titles and abstracts were screened independently by two of the authors (L.D. and S.G.G.) if they were believed to be relevant by any of the authors. Included in the reference list were original articles and case series that described or discussed any important aspects of maternal CPR or perimortem CS. Excluded from the final review were case reports that did not contain information and facts of high clinical impact. The reference list of included articles was specifically searched for further references. The initial search retrieved 4085 titles. Following this first stage of screening, a total of 202 articles were retrieved and further evaluated by the two authors, of which 81 articles were eventually included for primary review. Scanning the references resulted in inclusion of an additional 44 articles. In total, 65 articles were included in the final report, of which 24 were reviews, 10 cohort studies, nine guidelines, seven surveys, eight case reports, two randomized trials, and five other reports. For the purpose of this review, we defined maternal outcome as alive or dead after intent for CPR and neonatal outcome survival as without or with adverse neurologic sequelae. We did not attempt to analyze the composite data statistically because of the heterogeneity of the studies included, and a heterogeneity index calculation for the purpose of a meta-analysis was beyond the scope of this review.

Results

Incidence

Accurate data or registry information from which to derive the exact incidence of maternal collapse and perimortem CS could not be found. However, we were able to estimate the incidence based on reports from various regions around the world. In the UK, the rate of maternal collapse was estimated at between 1.4 and 60/10 000 deliveries according to confidential enquiries into maternal deaths between 2003 and 2005 (16,18). A retrospective questionnaire and medical records survey of nationwide data from the Netherlands for a period of 15 years (1993–2008) identified 55 women who suffered cardiac arrest, representing 0.18/10 000 deliveries; 12 (22%) of those women had undergone a perimortem CS (19). An extensive data review from a single Canadian center between 1989 and 2011 showed the incidence of maternal collapse to be 0.4/10 000 deliveries (20). In the USA, the incidence of maternal collapse was calculated to be 0.8/10 000 hospitalizations (21).

Overall, until 1986, a total of 188 cases of perimortem CS had been reported (12). The literature search showed that a review published for the period 1986–2004 identified 38 additional cases (14) and that a second review between 1980 and 2010, which partially overlapped the first, identified 94 cases (22).

Maternal deaths potentially requiring perimortem CS occurred as a result of diverse etiologies; the most common causes were trauma, maternal heart disease, eclampsia and amniotic fluid embolism (22).

Maternal outcome

Maternal survival following perimortem CS, varying greatly among the different studies, ranging between 34 and 54% (14, 22).

Current maternal CPR or CPR guidelines advocate manual left uterine displacement or firm wedge left lateral shift during maternal chest compression (17). The combination of a reduction in functional residual capacity due to diaphragmatic displacement by the gravid uterus (17) and the elevated metabolic demand in pregnancy (23) make the pregnant woman susceptible to rapid development of hypoxemia (12,14). During CPR, only 25–40% of the cardiac output is generated by chest compression (24); thus, additional compromise imposed on this minimal generated cardiac output by the enlarged uterus, may be critical. Delivery of the fetus relieves inferior vena cava occlusion, reduces the proportion of cardiac output directed to the uterus, and restores diaphragmatic placement, thereby presumably facilitating more efficient resuscitation (25,26).

When maternal cardiac arrest occurs in early gestation, perimortem CS is not likely to be beneficial to maternal survival; the smaller the fetal–placental mass, the less beneficial its removal for maternal hemodynamics. It has become acknowledged that with a uterine volume corresponding to 22–24 weeks, the contribution of delivery to maternal return of spontaneous circulation is limited and hence is not recommended by several authors (27–29). In late gestation, however, when the uterine volume (mechanical) effect along with peak maternal hemodynamic adaptation are significant, it remains unresolved whether perimortem CS at the time of maternal CPR efforts improves maternal cardiac output. At this time, the issue of fetal viability, beyond the pathophysiological underpinnings, might have some impact. Several case reports of perimortem CS during maternal cardiac arrest in late pregnancy describe positive resolution of apparently refractory maternal cardiac arrest (30–33) as a result of perimortem CS. Some authors have gone so far as to state that perimortem CS may be the most valuable part of maternal resuscitation (12). In a review of 38 perimortem CSs performed for maternal cardiac arrest for various reasons, there were no reports of deterioration of maternal hemodynamic status after perimortem CS (14). Among 94 maternal resuscitation attempts, perimortem CS was associated with less prominent return of spontaneous circulation than when maternal resuscitation alone was performed. The authors suggested that perimortem CS could have been performed before return to spontaneous circulation in cases perceived to be less likely to result in viable resuscitation. Because 54% of perimortem CS cases seem to imply maternal benefit, and because there were no cases inimical to maternal survival, point-of-care assumptions about the success of maternal resuscitation should not preclude the decision (22) to attempt perimortem CS.

Fetal outcome

Fetal survival following perimortem CS varies between no successes to 89%, according to various studies (14,34–36).

Currently, a gestational age of 24 weeks is generally considered to be the threshold of fetal viability (37,38), but there is an accepted range from 22 (39) to 26 weeks (40), as per consensus and health systems around the world. As always, efforts to achieve fetal survival should be weighed relative to the burden of extreme prematurity.

Gestational age is an important variable, yet is often unavailable in an emergency. Gestational age is generally estimated relatively accurately by an early antenatal ultrasound in countries with good access to technology, in contrast to other regions where gestational age is estimated from the last menstrual period or is unknown. A bedside, point-of-care ultrasound examination can provide valuable information regarding both gestational age and fetal viability (41); however, this technology and/or trained technicians may not be immediately available (41). If the latter is the case, palpation of fundal height is a feasible alternative option for determining gestational age (29,35,42). When the uterine fundus is more than 3 cm above the umbilicus, the fetus is considered potentially viable. Potential conditions that may render this method of estimating gestational age unreliable include cases of multi-fetal pregnancy, morbid obesity, abdominal distention because of other morbidities, and intrauterine growth restriction (35).

There is conflicting evidence regarding the value of ascertaining a fetal heart rate prior to initiating perimortem CS. Some authors suggest that only fetuses presenting with a heart rate are salvageable, in which case if the fetal heart rate cannot be detected, the fate of the pregnancy should not be a factor in maternal management; however, for these authors, the effect of uterine size on maternal circulation is not accounted for (36). Others underscore the reliability of the tool used in detecting the fetal heart rate (stethoscope, Doppler examination or sonography) and cite cases of neonatal survival despite a putatively absence of fetal heart rate documentation (43,44).

If the fetus is considered viable by the local guidelines and with reference to available neonatal care, early initiation of perimortem CS may be critical to an optimal neonatal outcome. Summarizing reports between 1875 and 1985 of fetal salvage with postmortem CS, the time from maternal collapse to delivery was documented in 61 of 100 cases of surviving infants. Surviving neonates were usually delivered rapidly: 70% within five minutes and 95% within 15 minutes of maternal collapse (12). These results are the basis for the *four-minute rule* for fetal salvage (12). Since CPR became routine in the 1960s, approximately 16% of the cases described in this series

could potentially have benefited from CPR. A more recent series summarizing cases published after routine implementation of CPR, demonstrated that in most cases (93%) the four-minute cut-off was not applied, sometimes even when delivery occurred 10 min after the arrest (22), yet approximately half of the neonates survived. Others have stated that "given the number of reports of neonatal survival without adverse neurologic sequelae, when delivery occurred well after 5 min of maternal cardiac arrest, this rule should not be taken as absolute" (45). However, others report that more than 20% of the surviving neonates suffer from various levels of cerebral disability (22), which lends credibility to the suggestion that earlier fetal extraction may result in better fetal outcome. To date, these two studies remain the strongest evidence-based recommendations regarding perimortem CS.

Preparation for perimortem cesarean section

Advanced cardiac life support (ACLS) courses do not routinely train for obstetric catastrophes such as perimortem CS (46). To our knowledge, only two team-based training programs: MOET (Managing Obstetric Emergencies and Trauma) (47) and ALSO (Advanced Life Support in Obstetrics) (48) have been established to teach and train obstetric and emergency medicine caregivers for handling obstetric emergencies, including trauma. The foour-minute rule has been adopted in these training programs (28). It has been already shown that routine training of both anesthesiologists and obstetricians for a perimortem CS scenario significantly improves team management, role recognition, and performance during simulated events (34,49–53). In the only long-term study on this topic, the introduction of maternal emergency treatment courses was associated with improved adherence to guidelines and an increase in the use of perimortem CS (19). A portable model for simulation of perimortem CS is available. This model was recently tested within the training program at one education center and resulted in positive feedback (54).

Perimortem CS should be considered as soon as maternal collapse is diagnosed and thus, concurrent with resuscitation efforts, it is prudent to recruit surgical and neonatology assistance from on-call and other close-by teams. A recent study has demonstrated that these adjuncts are often neglected until rather late into the procedure (49). Since timely implementation of perimortem CS may be associated with improved outcomes, setting up a dedicated "maternity emergency code" may accelerate assembly of the necessary multi-disciplinary team.

Both anesthetic and obstetric staff should be made aware beforehand of the legal aspects of perimortem CS. Despite being an invasive procedure, in the emergency setting, perimortem CS should not be delayed in an attempt to obtain consent. The "doctrine of necessity" allows physicians to provide this treatment if it represents the best interests of the mother and child (12). To date, no civil or criminal charges have been levied against physicians performing a perimortem CS without consent of next in kin. On the contrary, two lawsuits have been filed in the USA for not performing a perimortem CS (55) in a timely fashion. One case involved a 28-week gravida who died of pulmonary embolism following an unsuccessful resuscitation in the emergency room and where perimortem CS was not performed; the lawsuit was denied (by the Colorado Court of Appeals) because the fetus did not meet the definition of a human being as being alive at the time of act and that performing a perimortem CS would not have altered maternal outcome to "a great degree of probability" (56). In the second case, the lawsuit cited delayed perimortem CS (not directly after maternal collapse) as the probable cause of fetal neurological impairment (57).

Management of perimortem cesarean section

Perimortem CS should be initiated when resuscitation efforts on a gravida with a potentially viable pregnancy does not result in return of spontaneous circulation within four minutes. It is thus imperative to note the precise time of maternal collapse and the time when CPR efforts are initiated. Resuscitation efforts must not be altered to accommodate the CS procedure, since maternal recovery is still possible. Rapid delivery is crucial for both mother and fetus. Hence, perimortem CS optimally should be performed at the site of the arrest. Patient transport during chest compression results in decreased compression effectiveness and additionally delays the advent of surgery (55,58,59). Routine preparations (such as placement of a urinary drainage catheter or surgical preparation of the abdomen) are time-consuming and therefore irrelevant. The person best suited to perform perimortem CS is the professional on location who is most skilled in CS. However, efforts should be made in parallel to recruit a skilled surgical team. Blood and blood products should be made immediately available, although these may not be available in cases of on-site resuscitation and will need to await transfer to the hospital.

Perimortem CS at the site of cardiac arrest in a non-dedicated setting may be challenging because of limitations such as poor lighting, lack of surgical tools, and suboptimal surgical field. Thus, a midline incision may be the best strategy for the CS and also for exploration of the abdominal cavity for a possible origin of bleed-

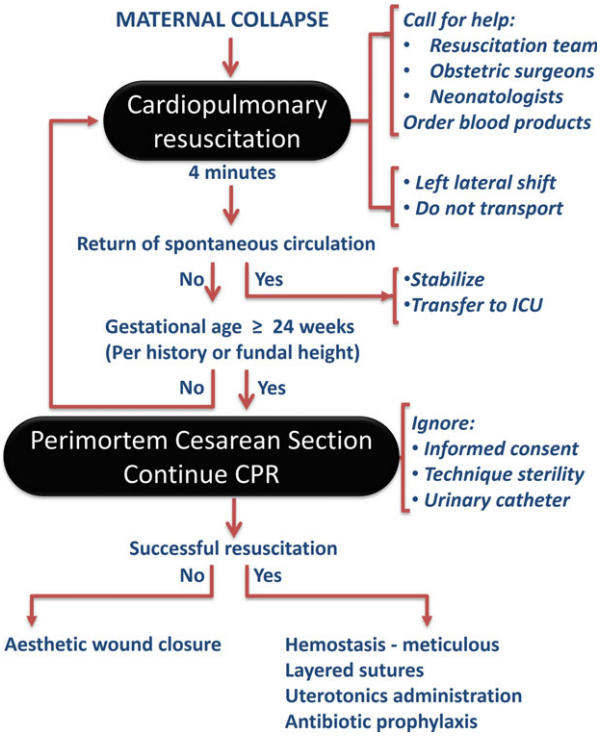

Figure 1. Resuscitation protocol in pregnancy following maternal collapse.

ing; a midline incision may also facilitate performance of hysterectomy if required for hemorrhage control (60). However, many obstetricians may feel more comfortable using approaches they are more familiar with and that may thereby save time, i.e. the Misgav-Ladach incision. Nonetheless, although rapid delivery is essential, protecting the fetus as well as the surrounding organs is equally important. The newborn should be put into the care of a neonatologist experienced in neonatal resuscitation. An umbilical cord loop should be double-clamped for blood gases analysis (although delaying the sampling up to an hour will not invalidate the results) (61). When maternal salvage is possible, prophylactic antibiotics and meticulous hemostasis must be achieved during layered closure of the abdomen. Since tissue perfusion during arrest is suboptimal at best, return of spontaneous circulation may be associated with reappearance of bleeding. Uterotonics should be used to limit uterine bleeding. Once return of spontaneous circulation has occurred, post-resuscitation syndrome may be accompanied by both thrombocytopenia (62) and coagulopathy (63).

Taking the above literature-based experience into account as well as considering the obstetrical care facilities likely to be available in most centers, we propose a simplified protocol for resuscitation following maternal collapse (Figure 1).

Discussion

Postmortem and perimortem CS are considered together because of comparable situations, but are ultimately intended to achieve divergent purposes and hence yield different outcomes. Postmortem CS was originally intended to preserve the burial and legal rights of the newborn, but that was in an era before the introduction of CPR. Without maternal CPR, maternal outcomes and most neonatal outcomes after post-mortem CS were thus almost universally disappointing. The concept of perimortem CS suggested in 1986 is currently endorsed by several prominent medical organizations; however, there is a dearth of relevant experience in the medical literature. The true incidence and outcome of perimortem CS is rarely reported and is inevitably biased towards better outcomes, whereas confidential enquiries (64) inevitably demonstrate negative selection bias. Analysis of near-miss reports is circumscribed because of the huge variability in definitions and diagnostic criteria (65); and case reports introduce confounders such as various etiologies that preclude generalizing about the outcome.

Based strictly on our understanding of the physiology, common-sense dictates that since the fetal–placental mass induces considerable aortocaval compression, its removal should be beneficial to the mother. Only one report has sought to validate this approach but concluded that only in approximately one-third of cases was there maternal benefit from perimortem CS, possibly because the procedure is more often attempted in cases thought less likely to have return of spontaneous circulation.

The likelihood of fetal viability (as determined by available information on gestational age and/or palpation of the uterine fundal height) should be the criterion for perimortem CS for the purpose of fetal salvage. However, current recommendations for the cut-off for viability vary between 22 and 26 weeks of gestation. The two reports on this specific topic imply that the fetus should be extracted within five minutes from the commencement of resuscitation efforts, regardless of the maternal outcome. If maternal CPR is ongoing, the likelihood of a good fetal outcome is greater with perimortem CS within a similar time frame, although good outcomes have been described after longer periods of maternal resuscitation.

Although informed consent is often not realistic, physicians should be aware that as a community they are not only medically mandated but also morally, ethically and legally required to perform perimortem CS. To avoid unnecessary delays, pre-event training programs, and a maternity emergency code system, should be implemented

as standard protocol prior to event occurrence. Once maternal collapse occurs, routine pre-surgical preparations should be put aside and perimortem CS should take place at the site of maternal collapse if possible. Although the authors are cognizant that the proposed simplified protocol for resuscitation following maternal collapse needs validation, it is provided here as a guideline to assist in resuscitation efforts.

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