Resuscitation 83 (2012) 1191–1200

Contents lists available at SciVerse ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Review article

Maternal cardiac arrest and perimortem caesarean delivery: Evidence or expert-based?☆,☆☆

Sharon Einav[a,*], Nechama Kaufman[a,b], Hen Y. Sela[c]

[a] The General Intensive Care Unit of the Shaare Zedek Medical Centre, Jerusalem, Israel
[b] The Department of Emergency Medicine of the Shaare Zedek Medical Centre, Jerusalem, Israel
[c] The Department of Obstetrics and Gynaecology, Division of Maternal Fetal Medicine, Columbia University Medical Center, New York, USA

ARTICLE INFO

Article history:
Received 26 January 2012
Received in revised form 29 April 2012
Accepted 2 May 2012

Keywords:
Heart arrest
Death
Sudden
Cardiac
Cardiopulmonary resuscitation
Pregnancy
Caesarean section
Hysterotomy

ABSTRACT

Aim: To examine the outcomes of maternal cardiac arrest and the evidence for the 4-min time frame from arrest to perimortem caesarean delivery (PMCD) recommended in current resuscitation and obstetric guidelines.
Data sources and methods: Review and data extraction from all reported maternal cardiac arrests occurring prior to delivery (1980–2010). Cases were included if they provided details regarding both the event and outcomes. Outcomes of arrest were assessed using survival, Cerebral Performance Category (CPC) and maternal/neonatal harm/benefit from PMCD. Outcome measures were maternal and neonatal survival.
Results: Of 1594 manuscripts screened, 156 underwent full review. Data extracted from 80 relevant papers yielded 94 included cases. *Maternal outcome*: 54.3% (51/94) of mothers survived to hospital discharge, 78.4% (40/51) with a CPC of 1/2. PMCD was determined to have been beneficial to the mother in 31.7% of cases and was not harmful in any case. In-hospital arrest and PMCD within 10 min of arrest were associated with better maternal outcomes (ORs 5.17 and 7.42 respectively, $p < 0.05$ both). *Neonatal outcome*: mean times from arrest to delivery were 14 ± 11 min and 22 ± 13 min in survivors and non-survivors respectively (receiver operating area under the curve 0.729). Neonatal survival was only associated with in-hospital maternal arrest (OR 13.0, $p < 0.001$).
Conclusions: Treatment recommendations should include a low admission threshold to a highly monitored area for pregnant women with cardiorespiratory decompensation, good overall performance of resuscitation and delivery within 10 min of arrest. Cognitive dissonance may delay both situation recognition and the response to maternal collapse.

Contents

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2012.05.005.
☆☆ The preliminary results of this study were presented as a lecture at the 2011 Annual Meeting of the American Society of Anesthesiologists, Chicago, IL, USA (SE) and as posters at the 2012 Annual Meeting of the Society for Maternal Fetal Medicine, Dallas, TX, USA (HYS).
* Corresponding author at: Surgical Intensive Care, Shaare Zedek Medical Centre, Affiliated with the Hebrew University, POB 3235, Jerusalem 91031, Israel. Tel.: +972 2 6666664; fax: +972 2 6555144; mobile: +972 508 685480.
E-mail address: einav_s@szmc.org.il (S. Einav).

0300-9572/$ – see front matter
http://dx.doi.org/10.1016/j.resuscitation.2012.05.005

1. Introduction

Maternal cardiopulmonary arrest with resultant death or disability carries devastating consequences.[1] Studies of cardiac arrest in the general adult population demonstrate that improving patient outcomes may be possible even in an arrest situation[2–4] but the efficacy of implementing similar strategies in maternal cardiac arrest remains unknown. The extreme rarity and highly uncontrolled circumstances of cardiopulmonary arrest during pregnancy render study of this medical situation very difficult.

Modern cardiopulmonary resuscitation (CPR) was first introduced in 1961.[5] Obstetric resuscitation first appeared in the guidelines only 30 years later[6]; less than a page was dedicated to the subject. Today, as evidenced by current resuscitation guidelines[7,8] and appearance of the first green-top guidelines on maternal collapse in pregnancy of the UK-based Royal College of Obstetricians and Gynaecologists (RCOG),[9] there is growing awareness that the physiological and anatomical changes of pregnancy may necessitate modification of standard practice.

Both resuscitation[7,8] and obstetric[9] guidelines suggest that perimortem caesarean delivery (PMCD) be considered within 4 min of maternal collapse if there is no return of spontaneous circulation (ROSC). Delivery within 5 min in women beyond 20 weeks of gestation is endorsed in order to facilitate maternal resuscitation (Grade D recommendation). This recommendation is based on the assumption that compression of the vena-cava by the gravid uterus[10] may interfere with maternal haemodynamics.[8] The 4 min interval theoretically benefits both mother and neonate by minimizing ischaemic neurological damage in both, but its veracity has never been studied.

The 4-min rule has been perpetuated in the literature due to two papers.[11,12] The first described a greater likelihood of neonatal survival with early PMCD in cases collected from 1875 to 1985.[11] Since CPR was first introduced in 1961,[6] clearly the large majority of women described in this paper did not undergo CPR. The second paper described the cases published between 1986 and 2004; time from arrest to PMCD was described only for surviving neonates ($n = 24$). This paper concluded that "... most resuscitation will be futile because the causes of maternal cardiac arrest are fatal".[12] Neither paper used Cochrane-style methodology, included arrest characteristics or performed a multivariate analysis.

We undertook this study to examine whether the assumptions regarding maternal and neonatal outcomes and the widely advocated 4-min time frame are justified based on the literature published on PMCD to date.

2. Materials and methods

Prior to study initiation, an internal protocol outlining the research question, outcome measures, search strategy, study selection, methods of data abstraction and analysis was developed.

2.1. Definitions and coding

PMCD was defined as "a caesarean delivery performed after initiation of cardiopulmonary resuscitation".[11]

Where the expression "term" was used to describe the gestational age,[13–18] we assumed 40 weeks gestation. One paper did not detail the gestational age of each case but described the minimal age for inclusion,[19] thus the earliest possible gestational age (26 weeks) was assumed for all cases described. Cases where the presenting rhythm was not detailed but the patient was described as going "into cardiac arrest" were grouped together as a separate category (i.e. "cardiac arrest").

2.2. Types of participants

Pregnant woman described as experiencing any one of the following occurrences prior to delivery: (1) "cardiac arrest" or a specific non-perfusing rhythm at any time and/or (2) report of treatment with chest compression and/or receipt of advanced life support medications and/or defibrillation. Cases with a presenting rhythm described as "cardiac arrest" were included only if this was followed by a description of the administration of basic and advanced life support. Cases describing administration of resuscitative medications only, with no description of a prior non-perfusing rhythm or the subsequent performance of chest compression/defibrillation, were not included in the study.

2.3. Types of studies

Published original articles, case series, case reports and letters to the editor were included, as well as reports from databases, provided that they met inclusion/exclusion criteria (listed below). Review papers were excluded. No language restrictions were applied for the search; however, for detailed data extraction, only papers in English, French, Japanese or German were included.

2.4. Inclusion criteria

Papers were included if they described cases for which the following data were provided: (1) At least five clinical details regarding the case (e.g. patient age, gravidity, parity, obstetric and medical history, presenting rhythm, location of arrest) and the care provided (e.g. chest compression, ventilation, monitoring, drug administration); (2) At least one of the following outcomes: (a) maternal non-return/return of spontaneous circulation or non-survival/survival to hospital discharge (SHD); (b) foetal/neonatal outcome.

2.5. Exclusion criteria

Papers were excluded if they described cases of maternal arrest occurring post-delivery, if there was no provision of data enabling relation of individual case details to outcome or if both outcomes were unclear. Appropriateness for inclusion was adjudicated by two reviewers (SE and HYS). If either was unsure regarding fulfillment of inclusion criteria, the paper was excluded from the analysis.

2.6. Outcome measures

The primary outcome measures were maternal and neonatal survival to hospital discharge and the relationship between PMCD and this outcome. Secondary outcome measures included maternal and neonatal neurological outcomes and the feasibility of performance of PMCD within the advocated time frame.

Outcomes were assessed through independent judgment by two reviewers (SE and HYS). PMCD was determined to have a beneficial effect on maternal outcome when a clear association between PMCD and maternal haemodynamic improvement was described. PMCD was determined to have a harmful effect on maternal outcome if it had led to a complication associated with maternal death. PMCD was determined to have a beneficial effect on neonatal outcome when there was no maternal ROSC (i.e. without PMCD the neonate would have died as well); exceptions to this rule were cases where the neonate survived with severe residual neurological damage. In general, the tendency was towards conservatism: if benefit was not obvious, there was judged to be no benefit.

The instrument used to assess neurological outcome was the Cerebral Performance Category (CPC) score. For the purpose of this study, the score was dichotomized to 1/2 for good to moderate neurological outcomes and 3/4 for poor to severe neurological outcomes. This clinical instrument is often used to assess the extent of brain damage after cardiac arrest in adults[20,21] as well as in pediatric populations[22] and has demonstrated inter-rater reliability[23]; furthermore, with a high CPC score, the likelihood of a good Health Utilities Index score is very low.[24]

Both maternal and neonatal CPC results were determined by two independent reviewers (SE and HYS) based on the description in the publication.

3. Search methods for identification of studies

3.1. Electronic databases

From Dec 2010 to Jan 2011 publications in the Cochrane and MEDLINE electronic databases were sought using the terms “pregnancy” or “pregnant” and “cardiac arrest” or “perimortem” or “postmortem” or “cardiopulmonary arrest” or “cardiopulmonary resuscitation” or “fatal outcome” or “maternal mortality” or “death” and “delivery” or “caesarean section” or “caesarean delivery”. Citation lists were independently searched by two of the authors (SH and HYS) to identify relevant studies. Titles and abstracts were screened and articles were retrieved if they were either clearly relevant or believed to be relevant.

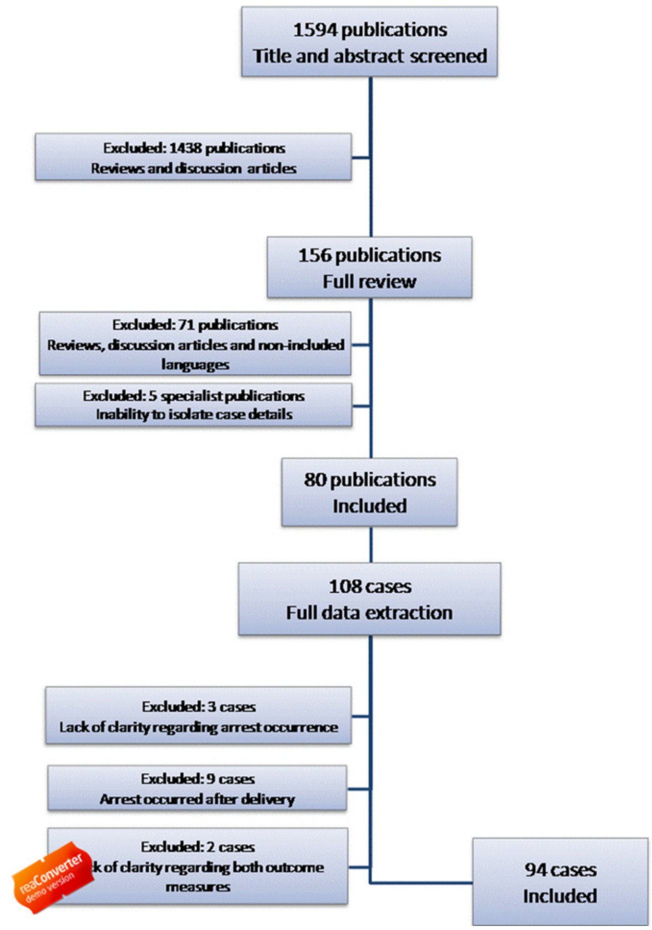

Fig. 1. Flow chart of inclusion process.

3.2. Reference lists

The reference lists of included and non-included papers (e.g. reviews) that had been retrieved in the search were searched manually for further references.

3.3. Hand searches

The main journals most likely to contain publications in this area (e.g. Resuscitation, Circulation, Critical Care Medicine, Intensive Care Medicine, Annals of Emergency Medicine, and the American, British and International Journals of Obstetrics and Gynecology) were identified using MEDLINE and content experts in the area. These were hand searched if they were locally available and had not already been included. Specialist publications[1,19,34] were similarly searched.

3.4. Selection of studies

If the title or abstract suggested presentation of a case eligible for inclusion, the full article was retrieved and reviewed against the inclusion and exclusion criteria. Critical appraisal of eligible cases was performed independently by two of the authors (SE and HYS). Only cases meeting inclusion criteria based on the assessment of both reviewers were kept for data extraction. Of the 1594 manuscripts screened through the title and abstract of the paper, 156 also underwent full review. From these papers, 108 cases underwent full data extraction and 94 cases were included in the final analysis (Fig. 1).

3.5. Assessment of risk of bias

All papers were either case reports or case series. As the level of evidence was considerably lower than that demanded of a systematic review, it was impossible to assess the risk of bias through accepted quality ratings of clinical trials.

3.5.1. Data management

Once included, data regarding each case were extracted using a pre-constructed list of variables. Information regarding each case, including potential triggers, sequence of events, arrest characteristics, pre-hospital (where relevant) and in-hospital case management and maternal and foetal/neonatal outcomes were independently extracted by two authors (SE and HYS). Differences were resolved by external consultation.

3.5.2. Data analysis

In the first step, descriptive statistics were used to characterize the study population. Continuous variables (e.g. maternal age, gestational age, parity, gravidity, time from arrest to delivery and cord blood pH) were described with their means, standard deviations, medians, ranges and interquartile ranges (IQRs); these were examined for their distributions. Categorical variables (e.g. type of pregnancy [singleton or not], causes and locations of arrest, witnessed status, presenting maternal rhythms, foetal heart rates, rates of maternal and neonatal survival and neurological outcomes) were described with proportions and percentages.

In the second step, descriptive statistics were used to study both outcome measures. The prevalence of the maternal outcome measure (i.e. maternal SHD) with/without PMCD was examined, including the reviewers' impression regarding the relationship between PMCD and maternal outcome (beneficial/unclear/harmful). The prevalence of the neonatal outcome measure (i.e. neonatal survival to hospital discharge) was appraised in relation to potential independent predictors (e.g. witnessed status, location of arrest, foetal heart rate monitor findings). The proportions of survivors/non-survivors for both mothers and neonates in relation to the relevant categorical independent variables were examined using either Chi-square or Fishers exact test (for tables with cells with a small expected number of cases).

The relationship between the outcome measures (maternal/neonatal SHD) and the independent variables potentially predicting these outcomes were examined using logistic regression modeling. In the first step, univariate associations between the outcome and the potential confounders were examined. Due to the small number of cases and the amount of unreported data, few variables were included in each model: witnessed status, location of the arrest, maternal presenting rhythm, gestational age and the amount of time from arrest to delivery were included in both maternal and neonatal models. Foetal heart rate was added to the neonatal model. Maternal presenting rhythm was first examined with ANOVA (data not presented) and then dichotomized when no between-group differences were found. The amount of time from arrest to delivery was examined both as a continuous variable (data not presented) and with cutoffs of 5, 10 and 15 min based on the recommendations and the median time observed in survivors. Similarly, foetal heart rate was first examined with ANOVA and then dichotomized. No colinearity was found between the two variables thought to be conceptually related: pre-hospital arrest and unwitnessed status. A choice was made to examine gestational age rather than birth weight because the number of cases with missing data was greater with the latter variable. The variables found to be statistically significant at the 0.10 level were entered in a multiple logistic regression model using the enter procedure.

Finally, the relationship between both neonatal and maternal survival and the time that elapsed between arrest to delivery was first examined using the *t*-test to compare between the groups (surviving and non-surviving) and then through ROC modeling. Data were analyzed using SPSS 18.0 (SPSS Inc., Chicago, Illinois).

4. Results

The literature search yielded 94 reported cases of maternal cardiac arrest during pregnancy (Fig. 1, Utstein). Average maternal age was 30.5 ± 6.5 years (median 32, range 17–44, IQR, 26.5–35.5, $n = 80$), gravidity 2.5 ± 1.5 (median 2, range 1–7, IQR 1–4, $n = 59$) and parity 1.1 ± 1.3 (median 1, range 0–6, IQR 0–2, $n = 57$). Most pregnancies were singleton (90.4%, $n = 85$) with an average gestational age at the time of the arrest of 33 ± 7 weeks (median 35, range 10–42, IQR 31–39, $n = 85$). Eight cases (8.5%) described arrest during twin pregnancy and one case described arrest during pregnancy with triplets.

4.1. Arrest characteristics

The most common causes of arrest were trauma, maternal cardiac problems, severe preeclampsia and amniotic fluid embolism. Most arrests occurred in-hospital (67.0%, $n = 63$) in highly monitored admission areas and most were witnessed (89.4%, $n = 84$); despite these facts, most of the women were not intubated prior to arrest (75.5%, $n = 71$). The most common presenting rhythm was asystole (25.5%, $n = 24$), followed closely by VT/VF (Ventricular Tachycardia/Ventricular Fibrillation) (24.5%, $n = 23$) and "cardiac arrest" (20.2%, $n = 19$). Patient outcome has been shown to be determined to a great extent by initial presenting rhythm; patients presenting with shockable rhythms [i.e. Ventricular Tachycardia (VT)/Ventricular Fibrillation (VF)] fare far better than those with initial non-shockable rhythms (i.e. asystole).[25] Further arrest characteristics are presented in Table 1.

4.2. Perimortem caesarean delivery

PMCD was performed in the majority of viable pregnancies (87.2%, 76/86). In 9 cases (10.5%), the mother was transported for this purpose to the operating room whilst undergoing CPR. Only 57 cases (75%) reported the time from arrest to delivery; the average time was 16.6 ± 12.5 min (median 10, range 1–60, IQR 8–25), with only 4 cases making it under the advocated 4-min time limit.

4.2.1. Maternal outcomes

4.2.1.1. ROSC. ROSC was achieved more often than not (60.6%, $n = 57$, data missing in 3 cases); of these women, 89.5% survived to hospital discharge (51/57). Overall survival to hospital discharge was 54.3% ($n = 51$). Maternal survival rates within each presenting rhythm are presented in Fig. 2A. Death occurred during the index arrest in 34 cases (36.2%), within 24 h in 4 cases (4.3%), within a week in one case (1.1%) and after more than a week in 2 cases (2.1%). Information regarding the time of death was not provided in three cases (3.2%). The variables predicting maternal survival are shown in Table 2; in multivariable analysis only in-hospital arrest location (OR = 7.42, CI 1.3–41.6, $p = 0.023$) and PMCD occurring within <10 min (OR = 5.17, CI 1.06–25.15, $p = 0.042$) achieved statistical significance.

4.2.2. Neurological outcomes

Outcomes of surviving mothers ($n = 51$) were described as CPC 1/2 in 78.4% (40/51), CPC 3/4 in 11.8% (6/51) and "good" in 9.8% (5/51) of the cases. Descriptions of residual neurological damage in surviving mothers included amnesia,[26] hemiparesis and dysarthria,[27] hemiplegia and speech impairment,[28]

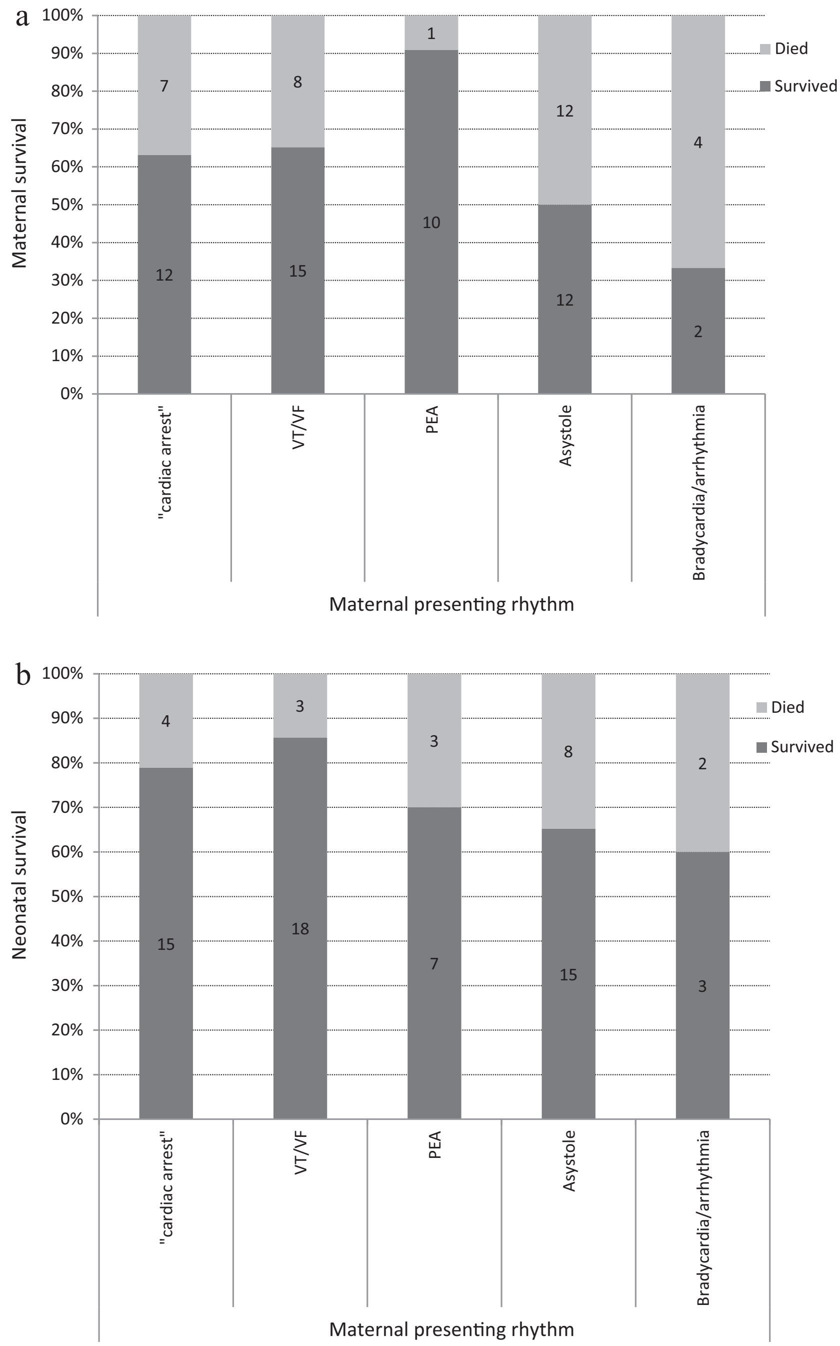

Fig. 2. (A) Proportion of maternal survival within each maternal presenting rhythm. (B) Proportion of neonatal survival within each maternal presenting rhythm.

impaired short-term memory,[29,30] neuropathic leg pain,[30] intention tremor[31] and visual field defects.[32]

4.2.2.1. PMCD. There were more cases of maternal ROSC without PMCD than with PMCD [93.8% (15/16) vs. 54.2% (39/72), $p = 0.005$], and there were more cases of SHD without PMCD compared to those with PMCD [87.5% (14/16) vs. 45.3% (34/75), $p = 0.002$]. In cases undergoing PMCD the average time elapsing from arrest to PMCD was significantly different between surviving (27/57) and non-surviving (30/57) mothers [10.0 ± 7.2 min (median 9, range 1–37) and 22.6 ± 13.3 min (median 20, range 4–60) respectively ($p < 0.001$, 95%CI 6.9–18.2)]. The area under the receiver operating curve (ROC) for prediction of maternal death by the time that elapsed from arrest to delivery was 0.827 (Fig. 3).

The reviewers agreed that PMCD had led to a clear maternal survival benefit in 19/60 cases (31.7%). The Lambda score achieved by the reviewers in correlation of outcome benefit was 0.617. There were no cases for which both reviewers agreed that PMCD may have been deleterious in terms of maternal survival.

4.2.3. Neonatal outcomes

Neonatal outcome is described for all cases not occurring during termination of pregnancy ($n = 92$), although only 86 pregnancies were viable at the time of the arrest.

4.2.3.1. Neonatal condition prior to PMCD and at birth. Reporting of foetal heart rate (FHR) monitoring would have been relevant in the

Table 1
Descriptive statistics of the study population arrest characteristics ($n = 94$).[13,26–32,49–113] Percentages are among all the reported cases, including those with missing data.

Characteristic	n	%
Primary cause of arrest		
Maternal cardiac complications (e.g. structural heart disease, cardiomyopathy)	18	19.1
Trauma	19	20.2
Complications of severe preeclampsia (incl. treatment complications, e.g. magnesium toxicity)	17	18.1
Amniotic fluid embolism	12	12.8
Toxicity (e.g. iatrogenic, complications of drug abuse)	8	8.5
Venous air embolism	4	4.3
Infection/sepsis	3	3.2
Aortic/coronary dissection	2	2.1
Uterine rupture	2	2.1
Primary pulmonary problem	2	2.1
Aortocaval compression syndrome	1	1.0
Unknown	5	5.3
Location of arrest		
Pre-hospital	27	28.7
In-hospital	63	67.0
Unknown	4	4.3
Location of in-hospital resuscitation		
Labour and delivery	25	26.6
Emergency department	24	25.5
Operating room	14	14.9
Intensive care unit	5	5.3
Antepartum ward	2	2.1
Ultrasound unit	1	1.1
Medical ward	1	1.1
Unknown	22	23.4
Witnessed status		
Witnessed	84	89.4
Unwitnessed	3	3.2
Unknown	7	7.4
Time of intubation		
After arrest	71	75.5
Before arrest	11	11.7
Unknown	12	12.8

86 cases with a viable pregnancy; however, in almost half of the cases, (48.8%, $n = 42$) FHR was either not assessed or not reported prior to PMCD. Among those cases where FHR was reported, the most common FHRs were bradycardia or decelerations (29.1%, $n = 25$) followed equally by "positive cardiac activity" and asystole (9.3%, $n = 8$ respectively). In four cases (3.5%), the FHR was described as "normal/reassuring" prior to PMCD. Cord blood pH was not reported in 81.4% of the cases (70/86) thus precluding any analysis using this variable.

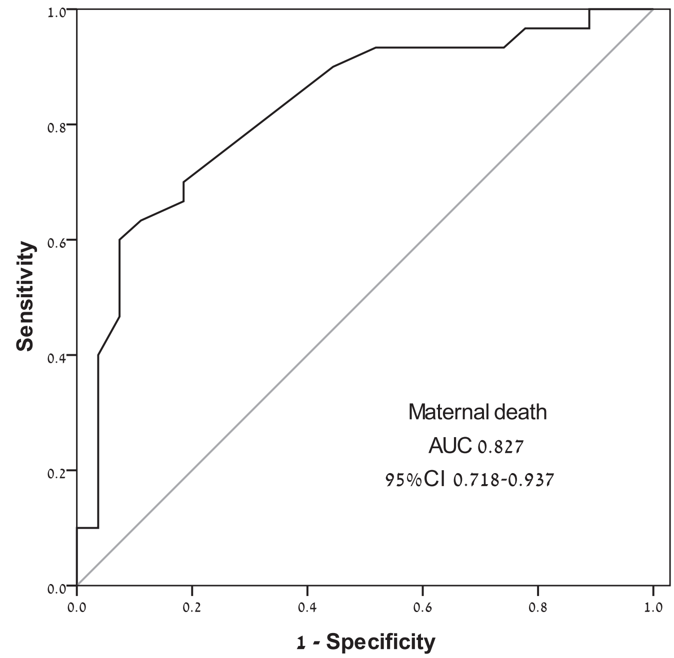

Fig. 3. ROC for predicting maternal death by time from arrest to delivery ($n = 57$). The area under the ROC curve was 0.827 (95%CI 0.718–0.937).

4.2.3.2. Singleton pregnancies with a potentially viable baby ($n = 77$). PMCD was performed in most cases (66/77, 85.7%) but neonatal outcome was not reported in two of these cases. In cases with PMCD which reported outcome, the overall neonatal survival rate was 63.6% (42/66). Outcomes of surviving neonates were described as CPC 1/2 in 52.3% (22/42), CPC 3/4 in 21.4% (9/42) and "good" in 26.2% (11/42) of the cases. Neonatal deaths (22/66, 33.3%) were declared shortly after PMCD in 54.5% (12/22), within 24 h in 22.7% (5/22), within a week in 9.1% (2/22) and more than a week after the event in 13.3% (3/22) of the cases.

PMCD was not performed in 11 viable singleton pregnancies. In one such case the mother died still carrying the fetus. The neonatal survival rate in this cohort was therefore 90.9% ($n = 10$). Among the survivors, neurological outcomes were CPC 1/2 in 5 cases (50%) and "good" in 5 cases (50%). None of the surviving neonates had a CPC of 3/4.

4.2.3.3. Multiple pregnancies ($n = 9$) with potentially viable babies ($n = 19$). PCMD was performed in all cases with a multiple pregnancy. Overall neonatal survival was 63.1% (12/19). CPC was described as 1/2 for 25.0% (3/12) of the surviving neonates and 3/4

Table 2
Logistic regression analysis of variables potentially predictive of maternal survival.

Variable	n	Univariable		Multivariable	
		OR (95%CI)	p-Value	OR (95%CI)	p-Value
Witnessed arrest	84/87	2.80 (0.24–32.10)	0.408	Not in model	
In-hospital arrest location	63/90	6.14 (2.23–16.88)	<0.001	7.42 (1.32–41.60)	0.023
Presenting rhythm (alternative models)					
VT/VF	23/83	1.25 (0.46–3.40)	0.662	Not in model	
PEA	72/83	7.56 (0.92–62.23)	0.060	13.1 (0.95–178)	0.54
Not asystole	59/83	1.95 (0.74–5.12)	0.175	Not in model	
Time from arrest to PMCD (alternative models)					
Yes, at any time	57/57	1.146 (1.06–1.24)	0.001	Not in model	
Within <5 min	4/57	3.625 (0.35–37.14)	0.278	Not in model	
Within <10 min	18/57	11.25 (2.74–46.26)	0.001	5.17 (1.06–25.15)	0.042
Within <15 min	32/57	8.80 (5.57–30.18)	0.001	Not in model	
Gestational age <28 weeks	16/85	1.28 (0.42–3.92)	0.663	Not in model	
Gestational age <30 weeks	20/85	1.135 (0.41–3.15)	0.808	Not in model	

Table 3
Logistic regression analysis of variables potentially predictive of firstborn neonatal survival in viable pregnancies. Among the 86 viable pregnancies there were two cases in which neonatal survival was not described. Overall, 57 of the 84 firstborn neonates whose outcome was described also survived.

Variable	n	Univariable		Multivariable	
		OR (95%CI)	p-Value	OR (95%CI)	p-Value
Witnessed arrest	75/77	1	<0.000	Not in model[a]	
In-hospital arrest location	57/80	17.35 (5.26–57.25)	<0.001	13.02 (2.85–59.54)	0.001
Presenting rhythm (alternative models)					
VT/VF	17/73	3.27 (0.67–15.9)	0.142	Not in model	
Not PEA	64/73	1.5 (0.34–6.7)	0.596	Not in model	
Not asystole	50/73	1.89 (0.64–5.61)	0.251	Not in model	
Time from arrest to PMCD (alternative models)					
<5 min	4/57	1.68 (0.16–17.26)	0.664	Not in model	
<10 min	18/57	6.86 (1.39–33.93)	0.018	2.62 (0.41–16.69)	0.307
<15 min	32/57	3.87 (1.23–12.2)	0.021	Not in model	
FHR detected	73/81	3.86 (0.85–17.6)	0.081	2.14 (0.22–20.93)	0.513
Gestational age >28 weeks	67/75	3.19 (0.71–14.22)	0.129	Not in model	
Gestational age >30 weeks	63/75	2.27 (0.63–8.27)	0.208	Not in model	

[a] Unwitnessed arrest synonymous with death.

for 16.6% (2/12). Outcome was described as "good" among 58.3% (7/12) and could not be determined in one of the survivors.

4.2.3.4. Neonatal outcome by variable. Firstborn neonatal survival rates within each presenting maternal rhythm are presented in Fig. 2B. Firstborn neonatal mortality was higher in pre-hospital (17/23, 73.9%) compared to in-hospital arrests (8/57, 14.0%). The variables that were thought to predict neonatal survival are shown in Table 3; the only variable found to be significant on multivariable analysis was in-hospital arrest location (OR = 13.02, CI 2.85–55.54, $p = 0.001$).

4.2.3.5. Time from arrest to delivery. The time elapsing from arrest to delivery was described in 57 cases, and was <4 min in only four cases. Mean times were 14 ± 11 min (median = 10, range = 1–47) and 22 ± 13 min (median = 20, range = 4–60) in neonatal survivors and non-survivors respectively ($p = 0.016$). The area under the receiver operating curve (ROC) for prediction of neonatal death by the time that elapsed from arrest to delivery was 0.729 (Fig. 4).

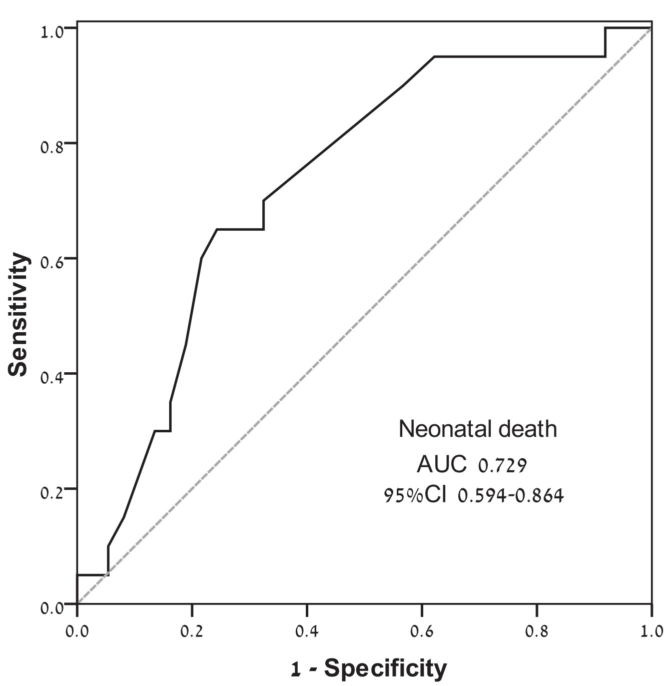

Fig. 4. ROC for predicting the death of the firstborn neonate by time from maternal arrest to delivery ($n = 57$). The area under the curve was 0.729 (95%CI 0.594–0.864).

4.2.3.6. Neonatal survival and PMCD. The reviewers agreed that PMCD had led to a clear neonatal survival benefit in 31/62 cases (50%). The Lambda score achieved by the reviewers in correlation of the neonatal outcome benefit of PMCD was 0.615. Both reviewers agreed that there were no cases where PMCD was deemed deleterious in terms of neonatal survival.

5. Discussion

The current study, based on analysis of pooled data from the published literature to date, highlights several important findings; maternal outcomes may not be as poor as those of other cardiac arrest populations, mortality rates were higher among women who underwent PMCD compared with those who did not, the 4-min time frame advocated for PMCD usually remains unmet yet neonatal survival is still likely if delivery occurs within 10 or even 15 min of arrest and neonatal survival was most-powerfully associated with maternal arrest occurring in-hospital, regardless of the cause of arrest.

The causes of maternal arrest described in the published cases comprising our study cohort were similar to those observed elsewhere[33–35]; however, survival rates within all rhythms were unusually high when compared to other cardiac arrest populations.[36] Either maternal cardiac arrest is a different entity than "regular" in- and out-of hospital cardiac arrests, or the published cases do not represent the entire population. Since the causes of arrest in this paper are reminiscent of those described elsewhere,[1] we assume that the majority of the difference should be attributed to the young and healthy baseline condition of most of the study population, the physiology of pregnancy, the unique precipitating causes and the high incidence of witnessed status.

The relationship between PMCD and maternal outcome remains unclear. There were higher mortality rates among women who underwent PMCD compared with those who did not, but this finding could be due to confounding (e.g. prolonged arrests having poorer outcomes and a higher likelihood of PMCD) or true causation. Although PMCD led to clear maternal survival benefit in only 31.7% of the cases, multivariate analysis suggests that this might be a powerful association. We therefore suggest that in the event of cardiac arrest, delivery should realistically occur within 10 min of arrest; by this time, the likelihood of maternal resuscitation is significantly decreased and there may well remain neonatal benefit. To date, approximately one-third of the women who die during pregnancy remain undelivered at the time of death.[1] Future research should determine the circumstances under which PMCD would maximally benefit both mothers and their children.

The 4-min time frame advocated for PMCD remained unmet in 93% of the cases, yet there was neonatal survival benefit in 50% of cases, even when delivery occurred >10 min after the arrest. Further research should focus on the role of cognitive dissonance in recognition and treatment delays in this situation. Fixation on specific time frames for PMCD may not be ideal. It may be more important to focus on event recognition and good overall performance. Training aimed at improving the teamwork and skills of all sectors of the obstetric resuscitation team have been advocated by many.[32,37–39] In a study recently performed in the Netherlands,[40] the frequency of PMCD increased after physicians participated in specialized courses, although the 4-min time frame remained elusive for them as well. It may be wise to advocate a short time frame for performance of PMCD in order to achieve better outcomes; however, blanket endorsement of an unrealistic time frame may well create a defeatist attitude when that time frame cannot be met.

Neonatal survival was most-powerfully associated with maternal arrest occurring in-hospital most likely because the likelihood of extrication of the neonate is improved if the mother cannot be resuscitated. Since elimination of unwitnessed arrests in hospitalized patients would improve both survival and subsequent neurological function,[41] treatment recommendations should include a low threshold of admission to a highly monitored environment for pregnant women showing early signs of cardiorespiratory decompensation. Further research should clarify the indications for admission and the relationship between highly monitored environments and patient outcomes in these cases.

The current study had several limitations, the key one being the need for a larger sample size to generate stable models and probability estimates; however this study encompassed most, if not all, of the literature on maternal cardiac arrest and PMCD published in the last 30 years. It may be prudent in the future to also consider other sources such as Embase, the grey literature and Web of Knowledge. As the results of this study rely entirely on previous publications, its conclusions should be interpreted with caution in light of possible recall bias, under-reporting and publication bias. Several studies have suggested that maternal mortality in general remains greatly under-reported, with rates of under-reporting ranging from 22% to 67%.[42–44] Finally, CPC estimates were performed indirectly by the authors based on the descriptions provided; however this assessment tool is a priori a very coarse assessment of patient condition.

6. Conclusions

Maternal cardiac arrest is a rare but haunting event. The National Registry of CPR (NRCPR) data demonstrates that such events occur at a reported rate of approximately 14 per year even within the United States.[41] To date, our ability to learn from these unfortunate occurrences, derive meaningful conclusions and optimize treatment is limited by poor reporting quality and possible reporting bias. The data from these cases should be systematically collected so that they may guide future preventive and therapeutic efforts.[1,45] Several countries have established systems to organize and collect such data.[46–48] Promulgation of maternal resuscitation guidelines would be much easier if the recommendations were evidence-based rather than expert-based. Considering the rarity of maternal arrest and the impact of such an event on all involved, international collaboration is warranted to advance knowledge of this subject and prevent the untimely deaths of young mothers and their children.

Conflict of interest statement

The authors state that there are no conflicts of interest, nor have they received any source of funding for this study.

References

1. Centre for Maternal and Child Enquiries (CMACE). Saving mothers' lives: reviewing maternal deaths to make motherhood safer: 2006–08. The eighth report on confidential enquiries into maternal deaths in the United Kingdom. Brit J Obstet Gynaec 2011;118:1–203. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1471-0528.2010.02847.x/pdf [accessed 20.09.2010].
2. Dichtwald S, Matot I, Einav S. Improving the outcome of in-hospital cardiac arrest: the importance of being EARNEST. Semin Cardiothorac Vasc Anesth 2009;13:19–30.
3. Hinchey PR, Myers JB, Lewis R, et al. Capital County Research Consortium. Improved out-of-hospital cardiac arrest survival after the sequential implementation of 2005 AHA guidelines for compressions, ventilations, and induced hypothermia: the Wake County experience. Ann Emerg Med 2010;56:348–57.
4. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation 2009;119:2597–605.
5. Safar P, Brown T, Holtey W, Wilder R. Ventilation and circulation with closed-chest cardiac massage in man. JAMA 1961;176:574–6.
6. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association, part IV: special resuscitation situations. JAMA 1992;268:2242–50.
7. Soar J, Perkins GD, Abbas G, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. Resuscitation 2010;81:1400–33.
8. Vanden Hoek TL, Morrison LJ, Shuster M, et al. Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010;122:S829–61 [Review].
9. RCOG. Maternal Collapse in Pregnancy and the Puerperium Green-top Guideline No. 56. January 2011. 24 p. Available at http://digitalrepository.e-medicinafetal.org/bitstream/10615/261/1/Maternal%20collapse%20in%20pregnancy%20and%20the%20puerperium%20RCOG%202011-3.pdf [accessed 09.02.11].
10. Ueland K, Novy MJ, Peterson EN, Metcalfe J. Maternal cardiovascular dynamics, IV: the influence of gestational age on the maternal cardiovascular response to posture and exercise. Am J Obstet Gynecol 1969;104:856–64.
11. Katz VL, Dotters DJ, Droegemueller W. Perimortem caesarean delivery. Obstet Gynecol 1986;68:571–6.
12. Katz V, Balderston K, DeFreest M. Perimortem caesarean delivery: were our assumptions correct? Am J Obstet Gynecol 2005;192:1916–21.
13. Richards A, Stather-Dunn L, Moodley J. Cardiopulmonary arrest after the administration of magnesium sulphate. A case report. S Afr Med J 1985;67:145.
14. Feldman JM. Cardiac arrest after succinylcholine administration in a pregnant patient recovered from Guillain–Barré syndrome. Anesthesiology 1990;72:942–4.
15. Awwad JT, Azar GB, Aouad AT, Raad J, Karam KS. Postmortem caesarean section following maternal blast injury: case report. J Trauma 1994;36:260–1.
16. McIndoe AK, Hammond EJ, Babington PC. Peripartum cardiomyopathy presenting as a cardiac arrest at induction of anaesthesia for emergency caesarean section. Br J Anaesth 1995;75:97–101.
17. Saha R. Perimortem caesarean delivery (PMCD). Kathmandu Univ Med J 2007;5:534–7.
18. Zdolsek HJ, Holmgren S, Wedenberg K, Lennmarken C. Circulatory arrest in late pregnancy: caesarean section a vital decision for both mother and child. Acta Anaesthesiol Scand 2009;53:828–9.
19. Morris JA, Rosenbower TJ, Jurkovich GJ, et al. Infant survival after caesarean section for trauma. Ann Surg 1996;223:481–91.
20. Brain Resuscitation Clinical Trial I Study Group (BRCT-1). Randomized clinical study of thiopental loading in comatose survivors of cardiac arrest. N Engl J Med 1986;314:397–403.
21. Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1975;1:480–4.
22. Fiser DH. Assessing the outcome of pediatric intensive care. J Pediatr 1992;121:69–74.
23. Ajam K, Gold LS, Beck SS, Damon S, Phelps R, Rea TD. Reliability of the Cerebral Performance Category to classify neurological status among survivors of ventricular fibrillation arrest: a cohort study. Scand J Trauma Resusc Emerg Med 2011;19:38.
24. Stiell IG, Nesbitt LP, Nichol G, et al. Comparison of the Cerebral Performance Category score and the Health Utilities Index for survivors of cardiac arrest. Ann Emerg Med 2009;53:241–8.
25. Meany PA, Vinay MN, Kern KB, et al. Rhythms and outcomes of adult in-hospital cardiac arrest. Crit Care Med 2010;38:101–8.
26. Wible EF, Kass JS, Lopez GA. A report of fetal demise during therapeutic hypothermia after cardiac arrest. Neurocrit Care 2010;13:239–42.
27. Shulte-Sasse U. Life threatening myocardial ischaemia associated with the use of prostaglandin E_1 to induce abortion. Brit J Obstet Gynaec 2000;107:700–2.
28. Oates S, Williams GL, Rees GAD. Cardiopulmonary resuscitation in late pregnancy. Brit Med J 1988;297:404–5.
29. Matsuo K, Lynch MA, Kopelman JN, Atlas RO. Anaphylactoid syndrome of pregnancy immediately after intrauterine pressure catheter placement: a case report. Am J Obstet Gynecol 2008;198:e8–9.

30. McDonnell NJ. Cardiopulmonary arrest in pregnancy: two case reports of successful outcomes in association with perimortem caesarean delivery. Brit J Anaesth 2009;103:406–9.
31. Lurie S, Mamet Y. Caesarean delivery during maternal cardiopulmonary resuscitation for status asthmaticus. Emerg Med J 2003;20:296–7.
32. Cardosi RJ, Porter KB. Caesarean delivery of twins during maternal cardiopulmonary arrest. Obstet Gynecol 1998;92:695–7.
33. Ronsmans C, Graham WJ. Lancet Maternal Survival Series steering group. Maternal mortality: who, when, where, and why. Lancet 2006;368:1189–200.
34. The Confidential Enquiry into Maternal and Child Health (CEMACH). Saving mothers' lives: reviewing maternal deaths to make motherhood safer – 2003–2005. In: The seventh report on confidential enquiries into maternal deaths in the United Kingdom. 2007. Available at http://www.mdeireland.com/pub/SML07_Report.pdf [accessed 15.09.10].
35. Hawkins JL, Koonin LM, Palmer SK, Gibbs CP. Anaesthesia-related deaths during obstetric delivery in the United States, 1979–1990. Anesthesiology 1997;86:277–84.
36. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14,720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation 2003;58:297–308.
37. Siassakos D, Crofts JF, Winter C, Weiner CP, Draycott TJ. The active components of effective training in obstetric emergencies. BJOG 2009;116:1028–32.
38. Siassakos D, Hasafa Z, Sibanda T, et al. Retrospective cohort study of diagnosis-delivery interval with umbilical cord prolapse: the effect of team training. BJOG 2009;116:1089–96.
39. Edwards S, Siassakos D. Training teams and leaders to reduce resuscitation errors and improve patient outcome. Resuscitation 2012;83:13–5.
40. Dijkman A, Huisman C, Smit M, et al. Cardiac arrest in pregnancy: increasing use of perimortem caesarean section due to emergency skills training? BJOG 2010;117:282–7, http://dx.doi.org/10.1111/j.1471-0528.2009.02461.x.
41. Brady WJ, Gurka KK, Mehring B, Peberdy MA, O'Connor RE. American Heart Association's Get with the Guidelines (formerly, NRCPR) Investigators. In-hospital cardiac arrest: impact of monitoring and witnessed event on patient survival and neurologic status at hospital discharge. Resuscitation 2011;82:845–52.
42. Deneux-Tharaux C, Berg C, Bouvier-Colle MH, et al. Underreporting of pregnancy-related mortality in the United States and Europe. Obstet Gynecol 2005;106:684–92.
43. Schuitemaker N, Van Roosmalen J, Dekker G, Van Dongen P, Van Geijn H, Gravenhorst JB. Underreporting of maternal mortality in The Netherlands. Obstet Gynecol 1997;90:78–82.
44. Donati S, Senatore S, Ronconi A, The regional maternal mortality working group. Maternal mortality in Italy: a record-linkage study. Brit J Obstet Gynaec 2011;18:872–9.
45. Pattinson RC, Hall M. Near misses: a useful adjunct to maternal death enquiries. Br Med Bull 2003;67:231–43.
46. Knight M, Kurinczuk JJ, Tuffnell D, Brocklehurst P. The UK Obstetric Surveillance System for rare disorders of pregnancy. Brit J Obstet Gynaec 2005;112:263–5.
47. The Australasian Maternity Outcomes Surveillance System (AMOSS). 2009. Available at http://www.pmmrc.health.govt.nz/moh.nsf/Files/pmmrc-presentations/$file/amoss.pdf [accessed 27.11.09].
48. NOSS-Nordic Obstetric Surveillance Study. 2009. Available at http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=4&ved=0CDQQFjAD&url=http%3A%2F%2Fwww.noss.nu%2Fuploads%2F2%2F2%2F8%2F9%2F2289978%2Fnfogworkshop1.ppt&ei=krcST_mwFIPNswbxtdFH&usg=AFQjCNHU77hN1lVhDxNcYzpzIQkI9BIBqg [accessed 27.11.2009].
49. Alderson JD. Cardiovascular collapse following epidural anaesthesia for Caesarean section in a patient with aortic incompetence. Anaesthesia 1987;42:643–5.
50. Araibi A, Maghrabia M, Sayed A, Loughrey JP, Blunnie WP, Geary M. Successful outcome for mother and twin babies following peri-mortem caesarean section. J Obstet Gynaecol 2007;27:860–1.
51. Balmain S, McCullough CT, Love C, Hughes R, Heidemann B, Bloomfield P. Acute myocardial infarction during pregnancy successfully treated with primary percutaneous coronary intervention. Int J Cardiol 2007;116:e85–7.
52. Baraka A, Kawkabani N, Haroun-Bizri S. Hemodynamic deterioration after cardiopulmonary bypass during pregnancy: resuscitation by postoperative emergency Cesarean section. J Cardiothorac Vasc Anesth 2000;14:314–5.
53. Bonini W, Botto GL, Broffoni T, Dondina C. Pregnancy with an ICD and a documented ICD discharge. Europace 2000;2:87–90.
54. Bowers W, Wagner C. Field perimortem cesarean section. Air Med J 2001;20:10–1.
55. Byhahn C, Bingold TM, Zwissler B, Maier M, Walcher F. Prehospital ultrasound detects pericardial tamponade in a pregnant victim of stabbing assault. Resuscitation 2008;76:146–8.
56. Campbell TA, Sanson TG. Cardiac arrest and pregnancy. J Emerg Trauma Shock 2009;2:34–42.
57. Capobianco G, Balata A, Mannazzu MC, et al. Perimortem cesarean delivery 30 min after a laboring patient jumped from a fourth-floor window: baby survives and is normal at age 4 years. Am J Obstet Gynecol 2008;198:e15–6.
58. Chen HF, Lee CN, Huang GD, Hsieh FJ, Huang SC, Chen HY. Delayed maternal death after perimortem cesarean section. Acta Obstet Gynecol Scand 1994;73:839–41.
59. Cohen WR, Steinman T, Patsner B, Snyder D, Satwicz P, Monroy P. Acute myocardial infarction in a pregnant woman at term. JAMA 1983;250: 2179–81.
60. Coke GA, Baschat AA, Mighty HE, Malinow AM. Maternal cardiac arrest associated with attempted fetal injection of potassium chloride. Int J Obstet Anesth 2004;13:287–90.
61. Rubery E, Bourdillon P, editors. Confidential enquiries into maternal deaths in the UK 1991–1993. London: HMSO Publications Centre; 1996.
62. Cordero DR, Medina C, Helfgott A. Cocaine body packing in pregnancy. Ann Emerg Med 2006;48:323–5.
63. Cordero DR, Toffle RC, McCauley CS. Cardiopulmonary arrest in pregnancy: the role of caesarean section in the resuscitative protocol. W V Med J 1992;88:402–3.
64. DePace NL, Betesh JS, Kotler MN. 'Postmortem' cesarean section with recovery of both mother and offspring. JAMA 1982;248:971–3.
65. Dezarnaulds G, Nada W. Perimortem caesarean section: a case report. Aust N Z J Obstet Gynaecol 2004;44:354–5.
66. Ellingsen CL, Eggebø TM, Lexow K. Amniotic fluid embolism after blunt abdominal trauma. Resuscitation 2007;75:180–3.
67. Emori T, Goto Y, Maeda T, Chiba Y, Haze K. Multiple coronary artery dissections diagnosed in vivo in a pregnant woman. Chest 1993;104:289–90.
68. Esposito MA, DeLony R, Goldstein PJ. Postmortem cesarean section with infant survival: a case report of an HIV-infected patient. Md Med J 1997;46:467–70.
69. Finegold H, Darwich A, Romeo R, Vallejo M, Ramanathan S. Successful resuscitation after maternal cardiac arrest by immediate cesarean section in the labor room. Anesthesiology 2002;96:1278.
70. Garner EG, Smith CV, Rayburn WF. Maternal respiratory arrest associated with intravenous fentanyl use during labor. A case report. J Reprod Med 1994;39:818–20.
71. Garry D, Leikin E, Fleisher AG, Tejani N. Acute myocardial infarction in pregnancy with subsequent medical and surgical management. Obstet Gynecol 1996;87:802–4.
72. Goldszmidt E, Davies S. Two cases of hemorrhage secondary to amniotic fluid embolus managed with uterine artery embolization. Can J Anaesth 2003;50:917–21.
73. Greenspoon JS, Masaki DI, Kurz CR. Cardiac tamponade in pregnancy during central hyperalimentation. Obstet Gynecol 1989;73:465–6.
74. Gupta B, Hartsilver E. Cardiac arrest during caesarean section for twins. Int J Obstet Anesth 2008;17:196–7.
75. Kaiser RT. Air embolism death of a pregnant woman secondary to orogenital sex. Acad Emerg Med 1994;1:555–8.
76. Kam CW. Perimortem caesarean sections (PMCS). J Accid Emerg Med 1994;11:57–8.
77. Kazandi M, Mgoyi L, Gundem G, Hacivelioglu S, Yücebilgin S, Ozkinay E. Postmortem Caesarean section performed 30 min after maternal cardiopulmonary arrest. Aust N Z J Obstet Gynaecol 2004;44:351–3.
78. Krishnamurthi S, Reddy SV, Mohamed M. Cardiomyopathy in pregnancy: 2 case reports. Singapore Med J 1989;30:208–9.
79. Kue R, Coyle C, Vaughan E, Restuccia M. Perimortem cesarean section in the helicopter EMS setting: a case report. Air Med J 2008;27:46–7.
80. Lanoix R, Akkapeddi V, Goldfeder B. Perimortem cesarean section: case reports and recommendations. Acad Emerg Med 1995;2:1063–7.
81. Lee PH, Shulman MS, Vellayappan U, Symes JF, Olenchock Jr SA. Surgical treatment of an amniotic fluid embolism with cardiopulmonary collapse. Ann Thorac Surg 2010;90:1694–6.
82. Lindsay SL, Hanson GC. Cardiac arrest in near-term pregnancy. Anaesthesia 1987;42:1074–7.
83. Lopez-Zeno JA, Carlo WA, O'Grady JP, Fanaroff AA. Infant survival following delayed postmortem cesarean delivery. Obstet Gynecol 1990;76:991–2.
84. Mabie WC, Anderson GD, Addington MB, Reed Jr CM, Peeden PZ, Sibai BM. The benefit of cesarean section in acute myocardial infarction complicated by premature labor. Obstet Gynecol 1988;71:503–6.
85. McCartney CJ, Dark A. Caesarean delivery during cardiac arrest in late pregnancy. Anaesthesia 1998;53:310–1.
86. Morau E, Valette S, Pirat P, Mottais F, Colson P. Amniotic fluid embolism during labor. Ann Fr Anesth Reanim 2002;21:744–7.
87. Morgan PJ. Maternal death following epidural anaesthesia for caesarean section delivery in a patient with unsuspected sepsis. Can J Anaesth 1995;42:330–4.
88. Morisaki H, Yamamoto S, Morita Y, Kotake Y, Ochiai R, Takeda J. Hypermagnesemia-induced cardiopulmonary arrest before induction of anesthesia for emergency cesarean section. J Clin Anesth 2000;12:224–6.
89. Nelissen EC, de Zwaan C, Marcus MA, Nijhuis JG. Maternal cardiac arrest in early pregnancy. Int J Obstet Anesth 2009;18:60–3.
90. O'Connor RL, Sevarino FB. Cardiopulmonary arrest in the pregnant patient: a report of a successful resuscitation. J Clin Anesth 1994;6:66–8.
91. Page-Rodriguez A, Gonzalez-Sanchez JA. Perimortem cesarean section of twin pregnancy: case report and review of the literature. Acad Emerg Med 1999;6:1072–4.
92. Pan PH, Moore CH, Ross VH. Severe maternal bradycardia and asystole after combined spinal–epidural labor analgesia in a morbidly obese parturient. J Clin Anesth 2004;16:461–4.
93. Parker J, Balis N, Chester S, Adey D. Cardiopulmonary arrest in pregnancy: successful resuscitation of mother and infant following immediate caesarean section in labour ward. Aust N Z J Obstet Gynaecol 1996;36:207–10.
94. Paull J. A prospective study of dextran-induced anaphylactoid reactions in 5745 patients. Anaesth Intensive Care 1987;15:163–7.
95. Peitsidou A, Peitsidis P, Tsekoura V, et al. Amniotic fluid embolism managed with success during labour: report of a severe clinical case and review of literature. Arch Gynecol Obstet 2008;277:271–5.

96. Peters CW, Layon AJ, Edwards RK. Cardiac arrest during pregnancy. J Clin Anesth 2005;17:229–34.
97. Phelan HA, Roller J, Minei JP. Perimortem cesarean section after utilization of surgeon-performed trauma ultrasound. J Trauma 2008;64:E12–4.
98. Ray BK, Vallejo MC, Creinin MD, et al. Amniotic fluid embolism with second trimester pregnancy termination: a case report. Can J Anaesth 2004;51:139–44.
99. Rittenberger JC, Kelly E, Jang D, Greer K, Heffner A. Successful outcome utilizing hypothermia after cardiac arrest in pregnancy: a case report. Crit Care Med 2008;36:1354–6.
100. Rodgers L, Dangel-Palmer MC, Berner N. Acute circulatory and respiratory collapse in obstetrical patients: a case report and review of the literature. AANA J 2000;68:444–50.
101. Saitoh K, Motegi R, Hirabayashi Y, Shimizu R. Cardiac arrests probably induced by hypermagnesemia during anesthesia for caesarean section. Masui 1994;43:388–91.
102. Selden BS, Burke TJ. Complete maternal and fetal recovery after prolonged cardiac arrest. Ann Emerg Med 1988;17:346–9.
103. Shemin RJ, Phillippe M, Dzau V. Acute thrombosis of a composite ascending aortic conduit containing a Bjork–Shiley valve during pregnancy: successful emergency cesarean section and operative repair. Clin Cardiol 1986;9:299–301.
104. Sitras V, Raatiniemi L, Larsby K, Klingenberg C. Cardiopulmonary collapse during labour. Anesthesiol Res Pract 2010, http://dx.doi.org/10.1155/2012/707619.
105. Stehr SN, Liebich I, Kamin G, Koch T, Litz RJ. Closing the gap between decision and delivery – amniotic fluid embolism with severe cardiopulmonary and haemostatic complications with a good outcome. Resuscitation 2007;74:377–81.
106. Suner S, Jagminas L, Peipert JF, Linakis J. Fatal spontaneous rupture of a gravid uterus: case report and literature review of uterine rupture. J Emerg Med 1996;14:181–5.
107. Swartjes JM, Schutte MF, Bleker OP. Management of eclampsia: cardiopulmonary arrest resulting from magnesium sulfate overdose. Eur J Obstet Gynecol Reprod Biol 1992;47:73–5.
108. Tang G, Nada W, Gyaneshwar R, Crooke D. Perimortem caesarean section: two case reports and a management protocol. Aust N Z J Obstet Gynaecol 2000;40:405–8.
109. Turner R, Gusack M. Massive amniotic fluid embolism. Ann Emerg Med 1984;13:359–61.
110. Wake K, Takanishi T, Kitajima T, Hayashi K, Takahashi H, Sakio H. Cardiac arrest during emergency cesarean section due to peripartum cardiomyopathy – a case report. Masui 2003;52:1089–91.
111. Watt AH. Successful postmortem caesarean section following maternal intracranial haemorrhage. Scott Med J 1985;30:234.
112. Yildirim C, Goksu S, Kocoglu H, Gocmen A, Akdogan M, Gunay N. Perimortem cesarean delivery following severe maternal penetrating injury. Yonsei Med J 2004;45:561–3.
113. Yoshida M, Matsuda H, Fukuda I, Furuya K. Sudden cardiac arrest during cesarean section due to epidural anaesthesia using ropivacaine: a case report. Arch Gynecol Obstet 2008;277:91–4.