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Review

Maternal and neonatal outcomes following resuscitative hysterotomy for out of hospital cardiac arrest: A systematic review

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Abstract

Objective: To examine maternal and neonatal outcomes following Resuscitative Hysterotomy for out of hospital cardiac arrest (OHCA) and to compare with timing from cardiac arrest to delivery.

Methods: The review was registered with PROSPERO (CRD42023445064). Studies included pregnant women with out of hospital cardiac arrest and resuscitative hysterotomy performed (in any setting) during cardiac arrest. We searched MEDLINE, EMBASE, and Cochrane Central Register of Controlled Trials (CENTRAL), from inception to 25th May 2024, restricted to humans. We included randomised controlled trials, observational studies, cases series or case reports. Two reviewers independently assessed study eligibility, extracted study data, and assessed risk of bias using validated tools. Data are summarised in a narrative synthesis.

Results: We included 42 publications (one cohort study, three case series and 38 case reports) including a total of 66 women and 68 neonates. Maternal and newborn survival to hospital discharge was 4.5% and 45.0% respectively. The longest duration from collapse to resuscitative hysterotomy for maternal survival with normal neurological function was 29 min and for neonates was 47 min. There were reported neonatal survivors born at 26 weeks gestation with good outcomes. The certainty of evidence was very low due to risk of bias.

Conclusion: There are low rates of maternal survival following resuscitative hysterotomy for OHCA. There are documented neonatal survivors after extended periods of maternal resuscitation, and at extremely preterm gestations (<28 weeks). Further prospective research should assess both maternal and neonatal outcomes to better inform future clinical practice.

Keywords: Perimortem cesarean section, Resuscitative hysterotomy, Out-of-hospital cardiac arrest, Maternal health, Emergency Medical Services, Pregnancy

Introduction

Resuscitative hysterotomy (RH) is an emergency caesarean section performed for a woman in middle to late pregnancy who is in cardiac arrest. The procedure aims to improve the woman's chances of a return of spontaneous circulation by removing the aortocaval compression caused by the fetus.[1] Other terms used for this procedure include perimortem caesarean section or post-mortem caesarean delivery.

The European Resuscitation Council, the Australian and New Zealand Committee on Resuscitation, and the American Heart Association all recommend the procedure of resuscitative hysterotomy early after maternal collapse if there is no immediate response to cardiopulmonary resuscitation.[2–4] These guidelines have variations in the specific recommendations and are predominantly based on data from cases of in-hospital maternal arrest. Outcomes following resuscitative hysterotomy for out of hospital cardiac arrest (OHCA) may differ significantly when the arrest is less likely to be witnessed, there are no bystander chest compressions, there are delays to accessing a clinician competent in resuscitative hysterotomy, when there are limited personnel and equipment, and expert support (obstetric or neonatal) is not immediately available. In addition, the causes of in-hospital collapse are likely to be more reversi-

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ble than OHCA with up to a quarter of maternal cardiac arrests occurring due to complications of obstetric anaesthesia.[5]

The increasing availability of prehospital physicians capable of providing surgical interventions may lead to a rise in resuscitative hysterotomy in the out of hospital setting. When this capability is not available, ambulance clinicians will rapidly convey the patient to the emergency department. The rates of survival from resuscitative hysterotomy (in both mother and baby) following OHCA are unknown. Decisions to undertake the procedure after prolonged cardiac arrest are based on the clinician's assessment of survivability. These decisions are made in a time-critical manner and carry a significant emotional burden. Having a greater understanding of survival related to the timing of resuscitative hysterotomy could guide expectations and inform future guidelines.

The aim of this systematic review was to examine maternal and neonatal outcomes following resuscitative hysterotomy for OHCA and to assess any relationship with the time from cardiac arrest to delivery.

Methods

This systematic review was prospectively registered with PROSPERO in 2023 (CRD42023445064). It is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting framework.[6]

Definitions

Resuscitative hysterotomy was defined as a caesarean section performed for a pregnant woman in cardiac arrest. The time of cardiac arrest was assumed to be the time of loss of central pulse, start of chest compressions, or if not otherwise stated, the time of the emergency call to the ambulance service for the collapsed pregnant patient. The time of resuscitative hysterotomy was defined as the start time of the procedure.

Information sources and search strategy

We searched the following electronic bibliographic databases on 25th May 2024: MEDLINE, EMBASE, and the Cochrane Central Register of Controlled Trials (CENTRAL), from inception to the search date, restricted to humans. No language restrictions were applied. To identify potential ongoing trials, we also searched the International Clinical Trials Registry Platform (https://www.who.int/ictrp/en/). We additionally reviewed the reference list of included articles for potential additional articles. The search strategies for each database are provided in the Supplementary Appendix 1.

Eligibility criteria

We used the PEO (Population, Exposure, Outcome) format to frame the review question: What are the outcomes of patients following resuscitative hysterotomy for out of hospital cardiac arrest?

Population inclusion criteria were pregnant women (of any age) with out of hospital cardiac arrest (of any cause). Exclusion criteria were patients who had cardiac arrest after delivery or onset of cardiac arrest occurred in hospital or if there was inadequate data to link an individual case to outcome.

Exposure was defined as resuscitative hysterotomy performed in any setting at the time of cardiac arrest. Cases were excluded if caesarean section took place after return of spontaneous circulation (ROSC) or before loss of vital signs. There was no comparator.

The main outcome measures were (1) Maternal outcomes including (a) any ROSC, (b) event survival (ROSC with survival to intensive care admission), (c) survival to hospital discharge or 30 days, (d) neurological outcome at hospital discharge or 30 days and (2) Neonatal outcomes including (a) requirement for ventilation after delivery, (b) requirement for CPR after delivery, (c) event survival (ROSC with survival to intensive care admission), (d) survival to hospital discharge or 30 days, (e) neurological outcome at hospital discharge or 30 days. In addition, process outcomes were recorded for the time from cardiac arrest to resuscitative hysterotomy. Complete follow up of neonates for neurological status was deemed to be at 2 years or more.[7]

We included randomised trials, non-randomised controlled trials, observational studies (cohort studies and case-control studies), case series (defined as three or more patient cases), and case reports. Letters to the editor were only included if they described a case report which met the intervention inclusion and exclusion criteria. Animal studies, ecological studies, reviews, editorials, abstracts, and comments were excluded.

Study selection and data extraction

Following the literature searches, any duplicates were removed. Two reviewers (CL and TN) independently screened all titles and abstracts retrieved from the literature search (using the Rayyan platform at https://www.rayyan.ai) and excluded irrelevant citations. Any disagreement regarding inclusion or exclusion was resolved via discussion between the reviewers and in the event of any disagreement the full text was considered at the following stage.

Those studies considered for inclusion had full text reviewed against the inclusion/exclusion criteria by both reviewers. Where there was disagreement regarding eligibility it was resolved via contacting the author for further clarification or the opinion of a third reviewer (SC). For all papers in which there was missing data, CL contacted the lead author for unreported data or additional details. If the gestational age, time of resuscitative hysterotomy in relation to onset of cardiac arrest, and the event survival of at least one of the patients (woman or baby) were still not available then the study was excluded. The screening and eligibility appraisal process were repeated for the reference lists of the included studies. Neurological outcome for maternal and neonatal survivors was documented as the exact description in the text. In cases where both the start time of the resuscitative hysterotomy procedure and delivery time of the baby were documented, the start time for resuscitative hysterotomy was used as the reference point.

Risk of bias

The certainty of the overall evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) system.[8] The papers were cohort studies, case series and case reports. Two investigators (CL and TN) independently assessed risk of bias for the included studies. The ROBINS-I tool was used for observational studies[9] and the tool by Murad et al, was used for evaluating the methodological quality of case reports and case series.[10]

Data synthesis

Key data from included studies were narratively described onto a predefined data extraction form by CL and crosschecked by TN. Continuous variables (age of patient, gestational age, time from arrest to resuscitative hysterotomy) were described with medians, ranges

and IQR's. Categorical variables (location of arrest, cause of arrest, witnessed arrest, presenting rhythm in arrest, rates of maternal and neonatal survival) were reported as proportions and percentages.

Main types of data (continuous, dichotomous) and outcome statistics were reported. Where not precluded by statistical, methodological or clinical heterogeneity, we planned to undertake a meta-analysis to provide a pooled estimate of the incidence for each outcome. In the event that meta-analysis was inappropriate, we planned to undertake a narrative synthesis, in line with the SWIM guidelines.[11]

Analysis of subgroups or subsets

We had a predefined aim to analyse the subgroups of causes of arrest as medical or trauma, and the subgroups of resuscitative hysterotomy performed in the prehospital (PH) setting or after transfer to the in-hospital (ED/other) setting.

Results

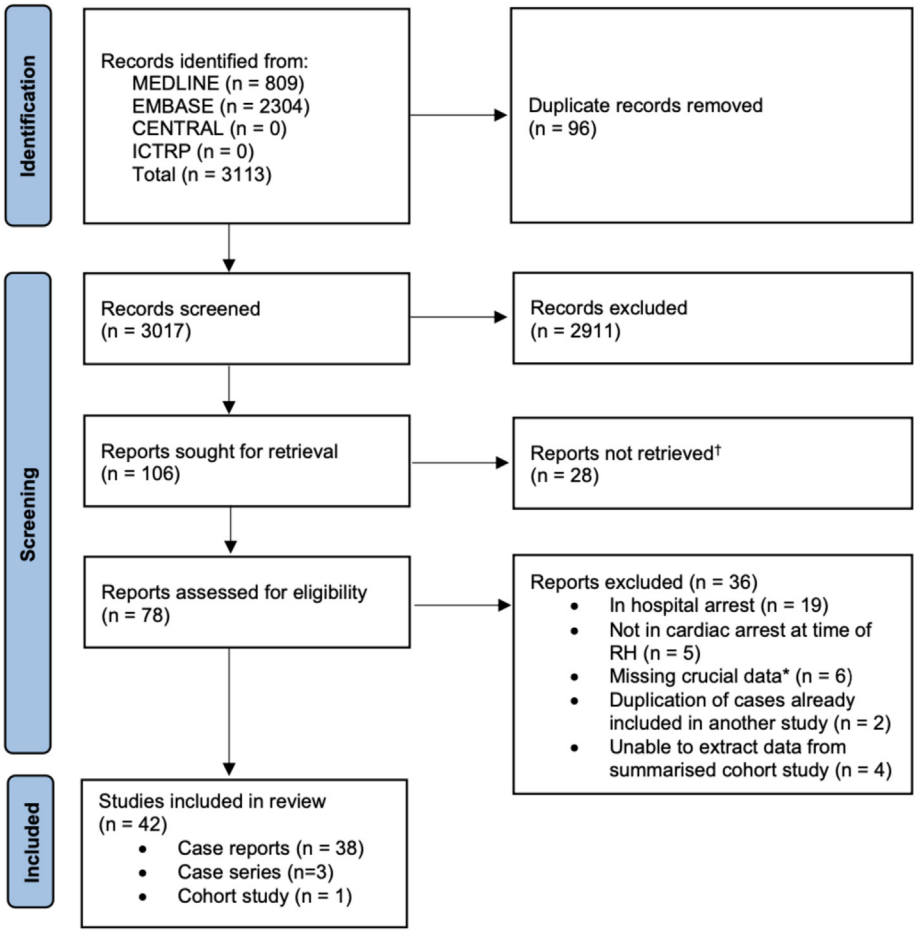
Our search identified 3113 publications, which after the removal of duplicate papers reduced to 3017 publications. Of these, 106 papers were considered potentially relevant based on a review of title and abstract and the full text articles were reviewed. No new studies were identified from the reference lists of these articles. After exclusion of papers which could not be retrieved and which did not meet the eligibility criteria, a total of 42 publications were included in the review (Fig. 1). As only case reports, case series and cohort studies were included we were unable to undertake a meta-analysis and report results narratively.

From these studies we included 38 case reports (41 mothers, 42 babies); 3 case series (13 mothers and babies); and 1 cohort study (12 mothers, 13 babies). This provided a total of 66 maternal cases with 68 neonatal cases. The settings included Asia (17, 25.7%), Australasia (4, 6.1%), Europe (36, 54.6%) and North America (9, 13.6%). Characteristics of included studies are documented in the Supplementary Appendix.[5,12–52]

Patient characteristics

Within the case reports/series the median maternal age was 30 years (range 17-44, IQR 25–35, *n* = 48). In the UK cohort study, the median maternal age was 34.5 years (range 21-39, IQR not available, *n* = 12).

For the case series/reports the median reported gestation of pregnancy at the time of resuscitative hysterotomy was 35 weeks (range 24-41, IQR 31–38, *n* = 54). In the cohort study, the median gestation was 30 weeks (range 20–40, *n* = 12).



† *A list of reports not retrieved can be found in supplemental appendices.*

"Crucial data" included gestation of pregnancy, *time of resuscitative hysterotomy in relation to onset of cardiac arrest, and the outcomes of the mother or baby.*

Fig. 1 – Study identification flow diagram.

Most pregnancies were singleton with two reported twin pregnancies. Ethnicity was rarely recorded and therefore these data were not extracted.

Arrest characteristics

There were 45 cases of medical arrest (68.2%) and 21 cases of traumatic cardiac arrest (31.8%). In 27 cases the location of arrest was at home (40.9%), with 13 cases occurring in a public place (19.7%), eight cases in the ambulance on route to hospital (12.1%), one case in private transport on the way to hospital (1.5%) and unknown location for 17 cases (25.8%). Where documented the arrest was reported to be witnessed in 23 cases (57.5%) and unwitnessed in 17 cases (42.5%). Bystander CPR was infrequently reported and occurred in only 4 out of the 13 cases witnessed by bystanders. Where documented, the presenting rhythm was shockable in 7 patients (20.6%) and non-shockable in 27 patients (79.4%). Further detail of arrest characteristics, including the cause of arrest where available, is provided in Table 1.

Resuscitative hysterotomy characteristics

Resuscitative hysterotomy was performed in the prehospital setting for 18 cases (27.3%) and after arrival in hospital in 48 cases (72.7%). The resuscitative hysterotomy operator was from an obstetric background in 22 procedures (33.3%) and was a non-obstetrician in 19 cases (28.8%), with an unknown operator in 25 cases (37.9%).

In the case reports/series the time from arrest to performing resuscitative hysterotomy was median 26.5 min (range 4–110, IQR 15-40, n = 54). In the cohort study the times were median 41.5 min (range 11–102, IQR 15-40, n = 12).

Maternal outcomes

From the 66 women, 20 patients had ROSC at any time during resuscitation (30.3%), 17 had event survival (25.7%), and 3 patients survived to hospital discharge (4.5%). Two surviving patients had pulmonary embolism (PE), and one had amniotic fluid embolism (AFE). Of the survivors, two women had normal neurological function (resuscitative hysterotomy performed at 15 minutes[5] and 29 minutes[39]) and one woman remained disabled and dependent on all care (resuscitative hysterotomy performed at 15 minutes[33]). Maternal survival to hospital discharge related to timing of the resuscitative hysterotomy is shown in Fig. 2.

Neonatal outcomes

The requirement for ventilation after delivery was inconsistently recorded (n = 52) but was documented as necessary in 50 patients and not required in 2 neonates. The requirement for CPR after delivery was inconsistently recorded (n = 44) but was documented as necessary in 40 patients and not required in 4 neonates. All neonates who transitioned without ventilations or CPR had survival with normal neurological status. In the 20 neonates reported to have received CPR with event survival, there was no follow up for one neonate, and 12 survivors to hospital discharge: 7 survivors were reported to be neurologically normal and 5 survivors to have disability.

From the 68 neonates, there were two babies of 20 weeks gestation (who were born without signs of life) but all others were of viable gestation (defined as >24 weeks) at the time of resuscitative hysterotomy. Outcome was unknown in four neonates from two case series. Of the remaining 62 babies, 42 survived to intensive care admission giving a neonatal event survival of 67.7%.

Table 1 – Descriptive characteristics of arrest for study population (n = 66).

	n	%
Type of arrest		
Medical	45	68.2
Traumatic	21	31.8
Location of arrest		
At home	27	40.9
Public place	13	19.7
In ambulance	8	12.1
In private transport	1	1.5
Unknown	17	25.8
Witnessed status		
Yes	23	34.8
By EMS	10	15.2
By bystanders	13	19.7
Unwitnessed	17	25.7
Unknown	26	39.4
Bystander CPR		
Yes	4	6.1
No	15	22.7
By EMS	10	15.2
Unknown	37	56
Presenting rhythm		
Shockable	7	10.6
PEA	10	15.1
Asystole	17	25.8
Unknown	32	48.5
Cause of arrest		
Medical		
PE	10	15.2
Cardiac	5	7.6
Hypovolaemia	5	7.6
ICH	3	4.6
AFE	3	4.6
Eclampsia	2	3
Aortic dissection	2	3
CO poisoning	1	1.5
Thyroid goitre	1	1.5
Hemophagocytic syndrome	1	1.5
Placental abruption	1	1.5
Seizures with hypoxia	1	1.5
Air embolism	1	1.5
Unknown	9	13.6
Trauma mechanism		
RTC	12	18.2
GSW	5	7.6
Fall from height	1	1.5
Knife injury	1	1.5
Blast injury	1	1.5
Electrocution	1	1.5
Location of RH		
Prehospital	18	27.3
Emergency Department	46	69.7
Labour suite	1	1.5
Theatre	1	1.5

Two neonates were not followed up to hospital discharge or 30 days (outcomes unknown). From the 40 remaining patients with follow up, there were 27 survivors to hospital discharge or 30 days. The overall survival rate to hospital discharge or 30 days for those with follow up was 27/60 babies of viable gestation born by resuscitative hysterotomy (45.0%).

Neonatal survival to hospital discharge related to timing of the resuscitative hysterotomy is demonstrated in Fig. 3.

Of the 27 survivors to hospital discharge there were neurological outcome data for 23 babies: 17 were reported as neurologically normal or to have mild developmental delay and 6 were reported to have more significant disability. However, follow up ranged from 6 days post-delivery to 8 years of age. Nine babies were followed up to two years or more, with 7 reported as having normal neurological status[12,16,21,42,43,46] (RH 15–35 min), one mild developmental delay[52] (RH 26 min) and one child with cerebral palsy[31] (RH 27 min).

There was neonatal survival with a reported good neurological outcome when resuscitative hysterotomy was performed up to 45 and 47 min post maternal cardiac arrest.[48,32] Neonatal survival to hospital discharge related to gestation at birth is reported in Fig. 4. The youngest neonate to survive following resuscitative hysterotomy with normal neurological status at two years follow up was 26 + 5 gestation.[42] There were two survivors in the 4 neonates born at extremely preterm gestation (<28 weeks), 5 survivors out of 7 very preterm gestation (28 to <32 weeks), and 8 survivors from 16 neonates of preterm gestation (32 to <37 weeks).

Subgroup analysis

There were 3/45 women who survived (6.6%) following medical causes of cardiac arrest and 0/21 survivors from traumatic causes of arrest. There were 17/38 neonatal survivors (47.3%) to hospital discharge following maternal arrest caused by medical causes and 10/20 (50.0%) neonatal survivors when the woman had cardiac arrest following traumatic injury.

There were 0/18 maternal survivors when resuscitative hysterotomy was performed in the PH setting (0%) and 3/48 maternal sur-

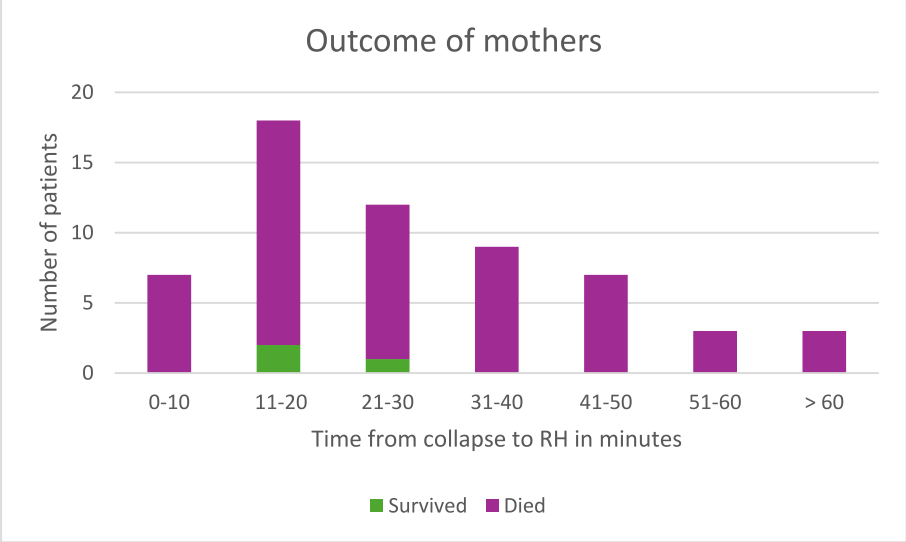


Fig. 2 – Maternal outcome related to timing of resuscitative hysterotomy.

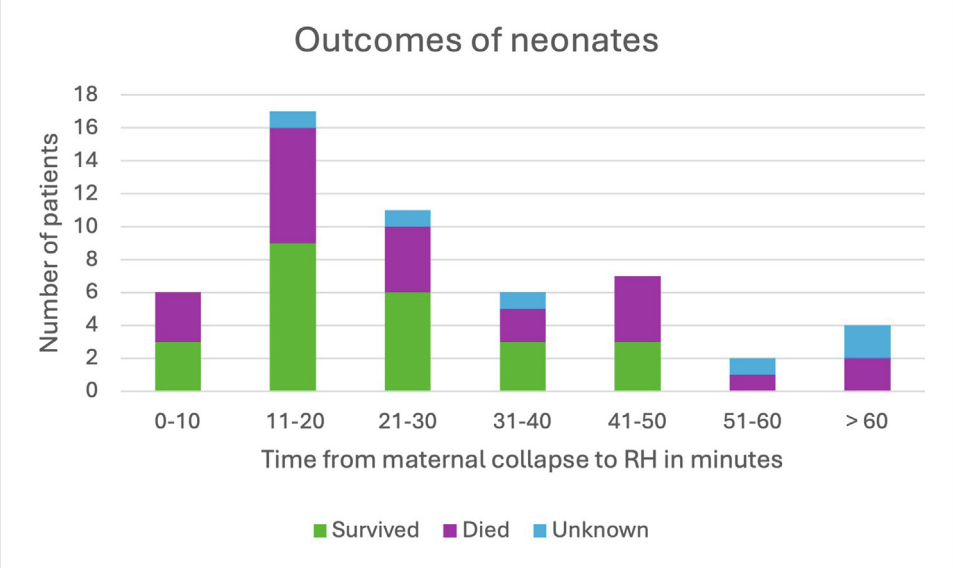


Fig. 3 – Neonatal outcome related to timing of resuscitative hysterotomy.

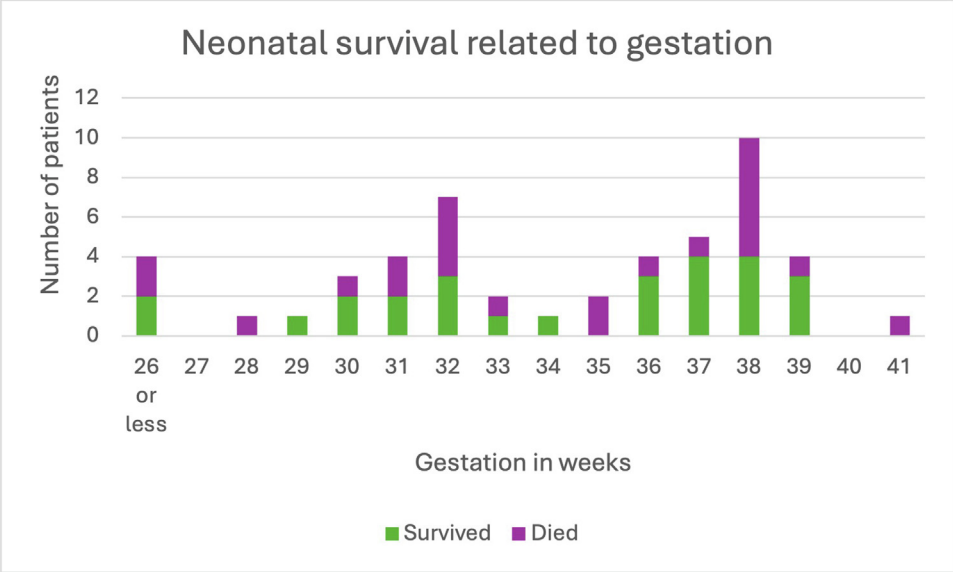


Fig. 4 – Neonatal outcome related to gestation at birth.

vivors (6.2%) when resuscitative hysterotomy was performed in the ED setting. In newborns with follow up there were 9/16 neonatal survivors when performed in the PH setting (62.5%) and 18/42 neonatal survivors (42.9%) when resuscitative hysterotomy was performed in hospital.

Risk of bias assessment

Risk of bias assessments are summarised in Supplementary Appendix 4.

Across all outcomes we assessed the evidence certainty as very low. (Supplementary Appendix 5).

Discussion

The aim of this systematic review was to examine maternal and neonatal outcomes following resuscitative hysterotomy specifically for OHCA and to compare with the time from cardiac arrest to delivery. In 66 cases of resuscitative hysterotomy, the rate of survival to hospital discharge was 4.5% in the women and 45.0% in the neonates.

The survival rates in this study differ from previous systematic reviews which have analysed in-hospital arrests combined with OHCA data. In a systematic review of maternal cardiac arrest up to the year 2010, 76 resuscitative hysterotomy procedures were reported with an overall maternal survival rate of 45.3% and a singleton pregnancy neonatal survival rate of 63.6%. The higher rate of survival in the previous review reflects that 67.0% were in-hospital cardiac arrests, 89.4% were witnessed, and 56.1% of patients had a resuscitative hysterotomy performed in <15 minutes.[53]

The underlying cause of maternal OHCA was commonly irreversible in the cases in this review. Katz reported that only 20/38 (52.6%) women had potentially resuscitable insults, even after exclusion of cases of resuscitative hysterotomy performed on trauma patients who were brought to ED after a protracted time post-injury.[54] In the review by Einav et al, the authors agreed that resuscitative hysterotomy had led to a clear maternal survival benefit in only 19/60 cases (31.7%).[53]

Historically, this procedure was called post-mortem caesarean section when performed in a deceased pregnant woman to save the life of the unborn child.[55] The term perimortem caesarean section was later used to reflect that the procedure was being undertaken at or around the time of death but during active resuscitation.[56] Resuscitative hysterotomy is now the most popular terminology as the primary objective is to achieve effective resuscitation of the pregnant woman and improve the chances of maternal survival.[57] However, this approach may have inadvertently moved the focus of resuscitation completely away from the unborn child. Neonates of viable gestation physiologically tolerate hypoxia in utero and during birth, and have been recognised previously to have a more favourable outcome than the mother following resuscitative hysterotomy[54,58] Whilst the primary objective is resuscitation of the pregnant woman, facilities must also be available for neonatal resuscitation when the fetus has reached a viable gestational age (currently if known or suspected by fundal height to be 24 weeks and above).[59] The findings of this review may also start a discussion around the appropriateness of resuscitative hysterotomy for fetal benefit if the mother were to have a condition unequivocally associated with death. However, such ethical debate is beyond the scope of this review.

There is uncertainty in current clinical practice as to when resuscitative hysterotomy would be considered futile and current guidelines do not suggest a 'cut off' time when the procedure would be contraindicated. In a case report by Söderberg et al, a pregnant woman of 24 weeks gestation collapsed in public and had a pulseless electrical activity arrest in the ambulance. Communication with the authors confirmed that resuscitative hysterotomy was performed in the ED at 29 minutes and thrombolysis was given after one hour (due to signs of pulmonary embolism on ultrasound) followed by a further 30 minutes of CPR before ROSC. The patient required blood transfusion and hysterectomy but was discharged from hospital neurologically normal.[39] The longest time to resuscitative hysterotomy with a neonatal survivor was described in the case report by

Lopez-Zeno where the mother sustained a gunshot wound to the face, abdomen and thorax and had an unwitnessed OHCA with no immediate bystander CPR for up to 25 minutes. Resuscitative hysterotomy was performed 47 minutes post injury in the ED to deliver a 32 week gestation infant. The exact time of cardiac arrest cannot be assured but postmortem revealed aortic injury suggestive of fatality within a few minutes of the injury. The child was followed up to 18 months and was reported to be clinically normal except for persistent, mild hypotonia and recurrent otitis media.[32] The case report by Yildriem at al, reported a similar case of penetrating trauma with resuscitative hysterotomy performed in the ED after 45 minutes of confirmed cardiac arrest, and normal child development six months after the event.[48] These cases, resulting in neurologically intact survivors, should prompt clinicians to consider resuscitative hysterotomy even after extended periods of maternal resuscitation.

Preterm gestation is defined as <37 weeks with extremely preterm less than 28 weeks and very preterm 28 to less than 32 weeks.[60] In this systematic review, neurologically intact survival at two years was reported following resuscitative hysterotomy as early as 26 + 5 weeks gestation.[42] 6/11 babies born at extreme or very pre-term gestation with known outcomes were reported to survive, with 83.3% having apparently normal development. Gestation may not be a useful discriminator for futility with respect to neonatal outcome as long as gestation for viability is met (currently 24 weeks).[59]

Regarding the sub-group analysis there were maternal survivors only after medical, and specifically thromboembolic, causes of arrest and all patients had the procedure performed after transfer to ED. Numbers are too small to make recommendations for future management but the maternal prognosis from traumatic cardiac arrest is particularly poor. By comparison, global survival rates to hospital discharge or 30-day survival after EMS-treated OHCA vary between 3.1–20.4%[61] depending on country and pooled survival rates in international studies of traumatic cardiac arrest are 2.8%.[62] There was no significant difference in neonatal outcome between medical or traumatic causes of maternal arrest. However, there was an improvement in neonatal survival when resuscitative hysterotomy was performed in the prehospital setting. Resuscitative hysterotomy performed by trained prehospital physicians at the location of collapse remains important to minimise delays to the procedure and improve the chances of a favourable outcome.

The chain of survival for out of hospital cardiac arrest includes early recognition and call for help, early CPR, early defibrillation, and post-resuscitation care.[63] Within this review there were gaps in data on the time from collapse to arrival of first EMS, the use of bystander CPR or AED use, and the presenting rhythm (which may have been shockable). Potential areas for improvement noted within the chain of survival for maternal cardiac arrest in this review include improving the low rates of bystander CPR (less than a third of witnessed cardiac arrests) and reducing delays to resuscitative hysterotomy. Future quality improvement projects should focus on these areas to improve outcomes from maternal cardiac arrest.

A major limitation of this review is the lack of high-quality data with most evidence provided from case reports and case series. The conclusions should be interpreted with caution considering possible under reporting and publication bias. In addition, the case reports originate from varying international geographical areas with significant differences in maternal health, prehospital care, and emergency department resources. There are several published cohort studies which include patients receiving resuscitative hysterotomy following OHCA but contact with the authors failed to provide the relevant extracted data. Not all neonates were followed up for sufficient time to establish a definitive neurological outcome and there was a lack of standardised disability scoring (for example Glasgow Outcome Score). The time of resuscitative hysterotomy was defined as the start of the procedure as this is used practically in the decision-making to perform the intervention. However, this does not take into account how long the procedure may take to perform and the benefits of aorto-caval decompression are only present after delivery. The time taken to undertake the procedure was reported in twenty-four cases with a median time of 2 min (range 1–5 min)[13,17,19,21,23,30,31,33,34,36,37,42,44,46,48,52] and one further outlying case of 15 min.[15] A strength of this study is that it specifically examines the prognosis from out of hospital cardiac arrest which is unique in the literature.

Future prospective observational research into the outcomes of OHCA in pregnancy should include accurate reporting of time from collapse to resuscitative interventions as well as completed follow up of mother and babies, including neurological status and developmental milestones to a minimum of two years for the neonates. It is also important to report the demographics of pregnant women sustaining cardiac arrest to identify inequalities due to ethnicity and socioeconomic status.

Conclusion

There are low rates of maternal survival following resuscitative hysterotomy for OHCA. There are neonatal survivors reported even after extended periods of maternal resuscitation, and at extremely preterm gestations (<28 weeks). Further prospective research should assess both maternal and neonatal outcomes to better inform future clinical practice.

CRediT authorship contribution statement

Caroline Leech: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tim Nutbeam:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Justin Chu:** Writing – review & editing, Methodology, Conceptualization. **Marian Knight:** Writing – review & editing, Methodology, Conceptualization. **Kim Hinshaw:** Writing – review & editing, Methodology, Conceptualization. **Tracy-Louise Appleyard:** Writing – review & editing, Methodology, Conceptualization. **Stephanie Cowan:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Data curation. **Keith Couper:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Joyce Yeung:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'KC is an editorial board member of Resuscitation. MK is an NIHR Senior Investigator. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.'.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resuscitation.2024.110479.

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