Can J Anesth/J Can Anesth (2013) 60:1077–1084
DOI 10.1007/s12630-013-0021-9

CASE REPORTS / CASE SERIES

Maternal cardiac arrest in a tertiary care centre during 1989-2011: a case series

L'arrêt cardiaque maternel dans un centre de soins tertiaires au cours de la période 1989-2011: une série de cas

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Received: 10 December 2012 / Accepted: 14 August 2013 / Published online: 14 September 2013

Abstract

Purpose *To review and report maternal and neonatal outcomes after cardiac arrest during pregnancy in a large tertiary care centre and to consider steps to improve the outcomes.*

Clinical features *We performed a retrospective chart review of maternal cardiac arrest in the Mount Sinai Hospital, University of Toronto health records database for the period 1989-2011. Five cases were identified for an incidence of 1:24,883 deliveries (0.004%). Four of the five women were obese and older than 35 yr. Two women had pre-existing cardiac conditions, and one had placenta accrete. All three underwent perimortem Cesarean delivery (PMCD), but none of these procedures was done within the recommended time of the "four-minute rule." Two of the three women had repeated arrests and subsequently died. The other two women were in labour, received regional analgesia, and had assisted vaginal deliveries. Both of these patients survived, and all survivors (mothers and neonates) were neurologically intact. Four of five neonates survived. The etiology of the cardiac arrest was indeterminate in all five cases, although suspected amniotic fluid embolism was considered the most likely contributing factor in the majority of cases. Overall, the quality of the charting was inconsistent and incomplete.*

Conclusions *This series of five cases highlights the challenges to meeting the rule of initiating PMCD within four minutes of maternal cardiac arrest onset. We suggest focusing on the quality of ongoing resuscitation efforts and early delivery as our experience shows that mother and neonate can survive beyond five minutes after arrest. Improved documentation and creation of a national database for these rare events should be considered.*

Résumé

Objectif *Passer en revue et rapporter les pronostics maternels et néonatals après un arrêt cardiaque pendant la grossesse dans un important centre de soins tertiaires et envisager des gestes pour améliorer les pronostics.*

Éléments cliniques *Nous avons réalisé une étude rétrospective des dossiers des patientes ayant subi un arrêt cardiaque maternel tirés de la base de données de dossiers de santé de l'Hôpital Mount Sinai, de l'Université de Toronto, entre 1989 et 2011. Cinq cas ont été identifiés, pour une incidence de 1:24 883 accouchements (0,004 %). Quatre des cinq femmes étaient obèses et âgées de plus de 35 ans. Deux femmes avaient des antécédents cardiaques, et une patiente présentait un placenta accreta. Toutes trois ont subi un accouchement par césarienne périmortem (ACPM), mais aucune de ces interventions n'a été réalisée dans la période recommandée par la « règle de quatre minutes ». Deux de ces trois femmes ont subi des arrêts répétés et sont décédées par la suite. Les deux autres femmes étaient en travail, ont reçu une analgésie régionale, et ont subi un accouchement vaginal assisté.*

This article is accompanied by an editorial. Please see Can J Anesth 2013; 60: this issue.

Author contributions *Leyla Baghirzada* reviewed charts, interpreted the findings, wrote the manuscript, and submitted the final version of the manuscript. Mrinalini Balki reviewed charts, interpreted the findings, and wrote and revised the manuscript.

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Ces deux patientes ont survécu, et tous les survivants (mères et nouveau-nés) n'ont pas eu de séquelles neurologiques. Quatre des cinq nouveau-nés ont survécu. L'étiologie de l'arrêt cardiaque était indéterminée dans les cinq cas, bien qu'une suspicion d'embolie du liquide amniotique ait été considérée comme le facteur contribuant le plus probablement à l'arrêt dans la majorité des cas. Globalement, la qualité des dossiers était inconstante et incomplète.

Conclusion *Cette série de cinq cas souligne les défis rencontrés lorsqu'on essaie de respecter la règle qui consiste à initier l'ACPM dans les quatre minutes suivant le début de l'arrêt cardiaque maternel. Notre suggestion est de concentrer notre attention sur la qualité des efforts de la réanimation en cours et l'accouchement précoce, étant donné que notre expérience montre que la mère et le nouveau-né peuvent survivre plus de cinq minutes après un arrêt. Une meilleure documentation et la création d'une base de données nationale rapportant ces événements rares devraient être envisagées.*

Cardiac arrest during pregnancy is a rare event, with a currently reported incidence of 0.02 per 1,000 deliveries (95% confidence interval 0.01 to 0.06) or 1:50,000 deliveries.[1] This incidence is less than the 1:30,000 incidence reported in the previous Confidential Enquiries into Maternal and Child Health report,[2] which constitutes the largest population-based data set for this target population. The fatality rate associated with this event is high, with maternal and neonatal case fatality rates of 83% and 58%, respectively.[3]

After maternal cardiac arrest, the survivals of the mother and the neonate depend on a number of factors, including the underlying reason for the arrest, site of the arrest, speed of resuscitative efforts, and the skills and resources of the health care providers.[1] The key intervention to save the mother and her infant is perimortem Cesarean delivery (PMCD), defined as a Cesarean delivery after cardiopulmonary resuscitation (CPR) has been initiated.[4] Both resuscitation and obstetrical guidelines suggest that PMCD should be initiated within four minutes of maternal collapse if there is no return of spontaneous circulation (ROSC), aiming at delivery of the fetus within five minutes after onset of cardiac arrest.[5-7] This recommendation originates from one case series[4] and experimental data[8,9] and is supported by a review of 38 published case reports of PMCD.[10] However, because the frequency of such events is low and the consequences are potentially catastrophic, within-institution review is warranted to determine compliance with recommended guidelines, review outcomes, and explore circumstances where the four-minute rule could not be followed. In part, as a quality assurance initiative, we undertook this project to review all cases of maternal cardiac arrest at our institution and to assess related maternal and fetal outcomes.

After receiving approval of the Research Ethics Board of Mount Sinai Hospital, (REB11-0196-C), a search of Mount Sinai hospital's health record database from January 1, 1989 to November 1, 2011 was undertaken to identify cases of maternal cardiac arrest. We used the diagnostic codes for cardiac arrest during pregnancy and obstetrical surgery procedures in women with admissions to antenatal, delivery, and postpartum services based on the International Classification of Diseases (ICD) ninth and tenth revisions (ICD-10-CA/CCI or ICD-9/CCP).[11] We included all cases in which the mother experienced circulatory arrest and CPR was initiated before delivery. Cases of isolated respiratory arrest or post-delivery circulatory arrest were excluded. The initial search identified nine cases, five of which met our inclusion criteria.

Case descriptions

Patient characteristics and details of the cardiac arrests for all five cases are summarized in Table 1. The neonatal outcomes are presented in Table 2.

Case 1

A 21-yr-old morbidly obese gravida 3, para 2 (G3P2) parturient at 32 weeks' gestation[4] presented in labour with preterm, premature rupture of membranes. Her past medical history was notable for insulin-dependent diabetes mellitus (DM) and asthma. The anesthesiologist performed a combined spinal epidural (CSE) and administered 0.25% bupivacaine 1 mL and sufentanil 7.5 μg intrathecally. Ten minutes following the CSE, the patient became unresponsive and appeared catatonic with pulseless electrical activity (PEA). Cardiopulmonary resuscitation was instituted. Vaginal examination by the obstetrician revealed full cervical dilatation, and the patient delivered with vacuum suction, approximately 14 min after the arrest. Resuscitation efforts were successful, and ROSC occurred approximately ten minutes after delivery. The endotracheal tube was reportedly full of blood. Bronchoscopy findings were consistent with diffuse airway hemorrhage. Amniotic fluid embolism (AFE) and total spinal anesthesia were noted in the chart as probable causes of arrest. After the arrest, transesophageal echocardiography showed mild pulmonary hypertension and right ventricular (RV) hypokinesis. The intensive care unit (ICU) stay was complicated by hemodynamic instability and prolonged respiratory failure

Table 1 Summary of cases of maternal cardiac arrest at Mount Sinai Hospital: 1989-2011

Case	Demographic data	Co-morbidities	Mode of delivery	Time from arrest to delivery	Time to ROSC	Location of arrest	Probable cause of arrest	Rhythm	Maternal morbidity outcome	Comment
1	21 yr, G3P2, 33 weeks' gestation, East Indian (1999)	Obese, IDDM and asthma	Vaginal (vacuum)	14 min	25 min	In hospital, labour ward	AFE/ PE/ total spinal	PEA	ARDS, airway haemorrhage Survived, neurologically intact; three uncomplicated deliveries subsequently	Became unresponsive 10 min following administration of CSE for labour. CSE noted to be technically difficult. Bright red blood in the endotracheal tube noted following bedside tracheal intubation
2	37 yr, G5P0, 41 weeks' gestation (2002)	Healthy, obese	Vaginal (vacuum)	2 min	N/A	In hospital, labour ward	AFE	PEA	PPH Survived, neurologically intact	Became unresponsive while pushing during delivery; developed PEA arrest
3	38 yr, G4P0, 27 weeks' gestation, Hindu (2002)	H/o mechanical Ao valve and repaired Ao aneurysm	Cesarean	31 min after 1st arrest and 6 min after 2nd arrest	NA*	In hospital, antepartum ward	Unknown	Asystole followed by PEA and then VFib during the 1st arrest. 2nd arrest asystole	Died	Not in labour. Symptoms of light-headedness and nausea followed by PEA arrest (lasted 21 min). *ROSC for 4 min but had 2nd PEA arrest; CD followed. Resuscitation efforts terminated 17 min later
4	35 yr, G4P1, 27 weeks gestation, Caucasian (2009)	Obese, DVT, placenta accreta	Cesarean	6 min	NA	In hospital, operating room	DIC secondary to AFE	VFib initially but PEA during subsequent arrests	Died	Emergency CD for profuse vaginal bleeding. VFib 2 min after tracheal intubation. ROSC after 5 min but had repeated episodes of arrest accompanied by profuse vaginal bleeding
5	45 yr, G2P0, 38 weeks' gestation, Caucasian (2011)	Obese, H/o severe Ao regurgitation, Ao coarctation with stent, hypertension, embolic stroke	Cesarean	14 min	16 min	Out of hospital	Unknown	PEA	Renal failure, VTach Survived, neurologically intact	Out-of-hospital PEA arrest. Not in labour. Dramatic improvement after delivery

ROSC = return of spontaneous circulation; IDDM = insulin-dependent diabetes mellitus; AFE = amniotic fluid embolism; PE = pulmonary embolism; PEA = pulseless electrical activity; ARDS = adult respiratory distress syndrome; CSE = combined spinal epidural; PPH = postpartum hemorrhage; H/o = history of; Ao = aortic; VFib = ventricular fibrillation; CD = Cesarean delivery; DVT = deep vein thrombosis; DIC = disseminated intravascular coagulation; VTach = ventricular tachycardia

*ROSC 21 min after the first arrest

requiring ongoing ventilatory support and subsequent tracheostomy. Mother and neonate were discharged home, neurologically intact, after 38 days.

Case 2

A 37-yr-old G5P0 obese parturient (body mass index 32 $kg \cdot m^{-2}$) presented for induction of labour at 41 weeks' gestation. Other than obesity, her past medical history was unremarkable. She received epidural analgesia for labour and approximately 2.5 hr later started to push for delivery. Immediately after the first push, she became unresponsive and exhibited a PEA rhythm. Cardiopulmonary resuscitation was started, and the fetus was delivered vaginally using vacuum suction within two minutes of the arrest. The time of ROSC was not documented. The patient suffered a severe postpartum hemorrhage requiring massive transfusion, uterine artery embolization, and ICU admission, where she stayed for 48 hr. At the time of discharge (nine days after the event), the patient was neurologically intact. The neonate was intubated and cared for in the neonatal ICU for five days. There were no apparent neurological problems at the time of discharge. Four years later, the patient had another term pregnancy and delivered without complications.

Case 3

A 38-yr-old G4P0 woman at 26 weeks' gestation was admitted to Mount Sinai Hospital with a provisional diagnosis of gastroesophageal reflux. Her past medical history included bicuspid aortic valve with aortic regurgitation and an ascending aortic aneurysm (the Bentall procedure was done with a mechanical aortic valve prosthesis), treated hypothyroidism, gestational DM, and a recent cerebrovascular accident. Cardiac investigations had excluded acute coronary syndrome. During this admission, the patient underwent amniocentesis for a suspected fetal anomaly. On the same day, she started vomiting and sustained asystolic cardiac arrest. Her cardiac rhythm changed to ventricular fibrillation (VFib) according to the medical record, yet there was no documentation of attempted defibrillation. By the time Cesarean delivery (CD) was contemplated, the patient had ROSC. However, four minutes later she became asystolic once again. PMCD was initiated within three minutes of the second arrest, and the fetus was delivered three minutes later. Maternal resuscitation attempts were unsuccessful, and CPR was terminated 17 min later. Neonatal resuscitation was terminated after 16 min. There was no autopsy report for either mother or child. The documented possible causes of arrest included pulmonary embolism and aortic valve thrombosis. Bedside echocardiography at the time of ROSC did not show RV dilatation, and the aortic valve could not be clearly visualized. Left ventricular (LV) and RV systolic functions were severely reduced.

Case 4

A 35 yr-old morbidly obese (body mass index 55 $kg \cdot m^{-2}$) G4P1 parturient at 27 weeks' gestation[2] was admitted with vaginal bleeding. Her pregnancy was complicated by complete placenta previa and placenta percreta with extension into the right ureter. During admission, the patient developed a deep venous thrombosis of her right leg and underwent placement of an inferior vena cava umbrella filter. The same day, she reported a sudden onset of dizziness and became hypotensive. Because of excessive vaginal bleeding, four hours later she was transferred to the operating room (OR) for an emergency CD. Shortly after induction of general anesthesia, she became hypoxic and pulseless. The initial rhythm was VFib. Cardiopulmonary resuscitation proceeded as per the Advanced Cardiovascular Life Support (ACLS) protocol followed by ROSC after four minutes and delivery after six minutes of cardiac arrest. The patient developed frank coagulopathy and received a massive transfusion and inotropic support. Approximately 3.5 hr after delivery, the patient had a second PEA arrest, followed by a third PEA arrest ten minutes later. Resuscitative efforts were terminated four hours after the initial arrest. In the coroner's report, the cause of death was reported as disseminated intravascular coagulation and possible pulmonary embolism or AFE. Bedside echocardiography showed that the left and right ventricles were moving with poor endocardial definition.

Case 5

A 45-yr-old morbidly obese (BMI 42 $kg \cdot m^{-2}$) G2P0 parturient at 38 weeks' gestation presented to Mount Sinai Hospital for induction of labour. Her past medical history included a bicuspid aortic valve, aortic coarctation, and an endovascular stenting procedure done three years previously. The patient had a history of hypertension, embolic stroke, severe untreated aortic regurgitation, and moderate aortic stenosis. Upon arrival in the Emergency Department the patient was severely dyspneic, agitated, and cyanotic from the neck upward. During transfer from ambulance to stretcher, the patient went into cardiac arrest with an initial rhythm of slow PEA. Cardiopulmonary resuscitation was started immediately, and the patient was admitted to the Emergency Department with CPR in progress. Abdominal ultrasonography performed by the obstetrician showed fetal bradycardia. PMCD was initiated within ten minutes of arrival in the Emergency Department, with delivery after one minute and ROSC two minutes later. A male neonate weighing 2,290 g was delivered, with Apgar

Table 2 Neonatal outcomes

Case	Gestational age (weeks^{days})	Sex	Weight (g)	Apgar score*	Resuscitation	NICU (days)	Outcome	Comments
1	32^{4}	Male	2,370	2/6/7	Intubated for respiratory distress, no epinephrine, no chest compressions	27	Survived	Extubated on CPAP day 1
2	41	Male	4,000	4/8/NA	Intubated for respiratory distress, no epinephrine, no chest compressions	5	Survived	No active issues upon discharge
3	26^{6}	Male	1,000	1/1/1	Intubated, required epinephrine and chest compressions	N/A	Died	Resuscitative efforts were stopped after 16 min
4	27^{2}	Male	1,220	1/4/5	Intubated, given surfactant, chest compressions	7	Survived	Required dopamine infusion during NICU stay. Extubated and transferred to Saskatchewan on day 7
5	38	Male	2,290	1/3/4	Intubated on 2nd attempt, chest compressions	10	Survived	Extubated on day 1. Was cooled for hypoxic ischemic encephalopathy, but MRI did not show evidence of such. Active, alert, bottle-feeding at discharge

*Apgar score at one minute, five minutes, and ten minutes

CPAP = continuous positive airway pressure; NICU = neonatal intensive care unit; MRI = magnetic resonance imaging

scores of one, three, and four at one, five, and ten minutes, respectively. The neonate required tracheal intubation and chest compressions and was cooled in the neonatal ICU because ischemic encephalopathy was suspected. Subsequent magnetic resonance imaging did not confirm this diagnosis. The mother underwent therapeutic hypothermia in the ICU. Her course was complicated by acute renal failure (requiring hemodialysis), *Clostridium difficile*-induced diarrhea, and rhabdomyolysis. She required implantation of an automated cardiac defibrillator because of recurrent ventricular tachycardia. She eventually made a full neurological recovery and was discharged home 60 days after the PMCD with plans to reassess her cardiac disease to evaluate the most appropriate time for aortic valve surgery. The etiology of her arrest was unclear. Aortic dissection and acute pulmonary embolism were excluded on the basis of computed tomography findings. Transthoracic echocardiography results on the day following the event were essentially unchanged from previous findings. They showed mild global LV dysfunction, severe LV hypertrophy, poor visualization of the aortic valve, and a moderate gradient across the valve.

Discussion

Among 124,416 deliveries over a 22-year period in our institution, we identified five cases of maternal cardiac arrest. The incidence of cardiac arrest was thus one per 24,883 deliveries (0.004%), which is higher than that reported in the most recent literature.[1]

With the changes in the obstetrical population characteristics—women are now older, heavier, and have more complex medical and obstetrical problems during pregnancy[2]—it is likely that the number of women who develop serious co-morbidities during this period will increase. Four of five patients in our review were obese and older than 35 yr, two had significant underlying cardiac pathology, and one had abnormal, invasive placentation. The risk factors for cardiac arrest during pregnancy are likely multifactorial. Obesity, cardiac co-morbidities, and increased maternal age are known risk factors for maternal mortality.[12]

Despite underlying risk factors, the primary cause of cardiac arrest in the five patients in our study was indeterminate. The charts indicated, however, that AFE was contemplated in three of five cases based on clinical presentation. According to the UK Obstetric Surveillance System, the criteria for diagnosing AFE include (1) acute cardiovascular collapse of the parturient in the absence of any other clear cause and (2) the presence of one or more of the following: acute fetal compromise, cardiac arrhythmia or arrest, coagulopathy, convulsions, hypotension, hemorrhage, or related premonitory symptoms.[13] Amniotic fluid embolism most commonly occurs during labour or delivery or immediately postpartum and is thought to account for 5-15% of all maternal deaths in Western countries.[14] Among the risk

factors commonly associated with AFE, advanced age and DM were present in our patients. Obstetrical risk factors such as induction of labour, recent amniocentesis, and placenta previa were also present in selected cases of our series.[15]

Katz *et al.* reviewed 269 cases of maternal cardiac arrest that had occurred between 1879 and 1985, with 188 surviving infants.[4] Seventy percent of infants who had no neurological sequelae had been delivered within five minutes of maternal cardiac arrest. Therefore, the authors recommended that PMCD be performed within four minutes of maternal cardiac arrest and delivery of the infant within five minutes.[4] The theory is that effective CPR is extremely difficult in the pregnant patient at term. Compression of the great vessels by the uterus significantly reduces cardiac output, which means that chest compression in a pregnant patient allows generation of only 10% of normal cardiac output.[4,9] The rationale for PMCD is the following: If chest compressions do not produce a pulse, emptying the uterus is the next step to facilitate effective CPR and subsequently improve cardiac output. This, in turn, minimizes the risk of maternal neurological damage and improves the chance for fetal survival. Maternal hypoxia/anoxia can lead to irreversible brain damage within six minutes.[16] Although the fetus can survive hypoxia for a longer time because of compensatory mechanisms—higher fetal hemoglobin concentration and oxygen saturation, the ability to shunt blood to vital organs and reduce oxygen consumption during times of stress—the risk of neurological and respiratory sequelae increases with prolongation of the delivery time after arrest.[4] These recommendations for considering emergency CD according to the four-minute rule have been endorsed in recent American Heart Association guidelines.[6]

Only one patient in this series underwent delivery of the fetus within the recommended time frame (Case 2), and none of the PMCDs began within four minutes of arrest. The average time from arrest to delivery was 13 min (range 2-31 min). In surviving mothers, it was ten minutes (range 2-14 min). The time to ROSC varied from 16 to 25 min after the arrest and 2 to 11 min after emptying the uterus. In two cases where maternal cardiac arrest occurred outside the OR, no time was wasted to move the patient to the OR, and PMCD was performed at the bedside (Case 3) or in the Emergency Department (Case 5). Time-consuming activities such as fetal heart rate monitoring or ultrasonography were reported in only one case (Case 5) but did not appear to delay the decision to perform PMCD. Thus, we have observed survival of both mothers and neonates with delivery taking place up to 14 min after the arrest. Although adherence to the five-minute guide for delivery is often not achieved (according to data from existing studies) (Table 3), neonatal survival has been reported when delivery occurred within 15 min of maternal arrest when the arrest occurs in the hospital, regardless of its cause.[17] Although difficult to measure, the clinical goal of the shortest time frame for delivery should extend beyond simple neonatal survival and aim toward the best neurological neonatal outcome. During cardiac arrest, clinicians should focus attention on the quality of resuscitation efforts and early consideration of PMCD or vaginal delivery, with the five-minute rule of delivery serving as a guide. Our small case series indicates that some mothers and neonates survive despite not being delivered within the recommended five minutes.

For the cases reported here, CPR was initiated immediately after cardiac arrest was diagnosed, and resuscitation drugs were administered according to ACLS guidelines.[6] Poor maternal outcome was observed in cases that involved recurrent episodes of cardiac arrest. Because some pertinent details about the resuscitative efforts were not entered in the records, we are unable to comment on whether other ACLS-recommended, pregnancy-appropriate interventions were followed, such as placing support under the mother's back, manual left uterine displacement, switching compressors every two minutes, an adequate ventilation-to-compression ratio, correct positioning of the hand on the sternum, and utilization of cricoid pressure during tracheal intubation.[6] The position in which the mother was resuscitated was mentioned in only two cases: the left lateral decubitus position in Case 1 and the supine position in Case 4.

Vaginal deliveries in our series were associated with good maternal outcome regardless of the time between the arrest and delivery. This could be because these patients were either fully dilated or pushing at the time of arrest, allowing prompt delivery. The longest arrest to delivery time was 14 min. There is one case report of perimortem vaginal delivery that resulted in neonatal, but not maternal, survival.[18] The authors suggested that in cases where maternal cardiac arrest occurs at full cervical dilatation, perimortem instrumental vaginal delivery may be faster than CD and avoids the trauma and bleeding associated with surgery.

Our institution cares for more than 7,000 deliveries per annum and coordinates training programs and mock resuscitation drills in the management of obstetrical emergencies. These initiatives and the experience obtained from real-life cases led to the creation of dedicated PMCD equipment packs. These packs are located in the emergency department, on the labour and delivery floor resuscitation trolley that is sent to all hospital maternal cardiac arrests. The packs' contents include a disposable preloaded scalpel, sutures, needle holders, towel clips, retractors, forceps, scissors, suction tube, and uterine packs.

The infrequency of maternal cardiac arrest means that clinicians are rarely exposed to this condition. Various methods, including simulation[19] and written surveys,[20,21]

Table 3 Published case series of cardiac arrest during pregnancy

Reference	Study design/period	No. of patients with arrest/ PMCD	Causes of cardiac arrest	Time from arrest to PMCD	Survival rate in PMCD group
Einav *et al.* Resuscitation 2012[17]	Literature review of case reports, 1980-2010	Cardiac arrest, $n = 94$ PMCD, $n = 76$	Trauma, maternal cardiac problems, severe preeclampsia, AFE, toxicity, VAE, sepsis, aortic dissection, primary pulmonary problem, uterine rupture	<5 min for 4 cases <10 min for 18 cases <15 min for 32 cases	Maternal = 45% Neonatal = 63%
Dijkman *et al.* BJOG 2010[3]	Retrospective cohort, 1993-2008	Cardiac arrest, $n = 55$ PMCD, $n = 12$	AFE, severe preeclampsia, congenital heart disease, nonobstetrical hemorrhage, epilepsy, sepsis, trauma	5-15 min for 4 cases 16-31 min for 5 cases >31 min for 3 cases	Maternal = 17% Neonatal = 42%*
Katz *et al.* Am J Obstet Gynecol 2005[10]	Literature review of case reports, 1985-2004	Cardiac arrest, $n = N/A$ PMCD, $n = 38$	Trauma, cardiac, embolism, magnesium overdose, sepsis, anesthesia, eclampsia, spontaneous uterine rupture, intracranial hemorrhage	0-5 min for 11 cases 6-10 min for 4 cases 11-15 min for 2 cases >15 min for 7 cases[#]	Not reported, calculated as: Maternal = 34% Neonatal = 89%^
Katz *et al.* Obstet Gynecol 1986[4]	Literature review of case reports, 1879-1985	Cardiac arrest, $n = N/A$ PMCD, $n = 269$	Hypertensive disease, infection, trauma, aortic aneurysm, anesthesia, cardiac, malignancy, cerebrovascular event, asthma, embolism	0-5 min for 42 cases 6-10 min for 8 cases 11-15 min for 7 cases 16-20 min for 1 case 21+ min for 3 cases[#]	Not reported, calculated as: Neonatal = 70%
Baghirzada *et al.* (current study)	Case series, 1989-2011	Cardiac arrest, $n = 5$ PMCD, $n = 3$	AFE, anesthesia, disseminated intravascular coagulation	6-10 min for 1 case 11-15 min for 1 case >15 min for 1 case	N/A

*No maternal or neonatal survivors in out-of-hospital arrest group. No maternal survivors after 15 min of resuscitation and no neonatal survivors after 30 min of resuscitation

#Number of PMCDs with surviving neonates only

^Numerator includes two sets of twins and one set of triplets

AFE = amniotic fluid embolism; PMCD = perimortem Cesarean delivery; VAE = venous air embolism

have been used to assess the knowledge of maternal cardiac arrest. Despite mandatory ACLS certification for the obstetrical staff, knowledge of obstetrics-specific interventions and routine ACLS skills can remain poor.[19] A recent study by our group showed that both didactic teaching and electronic learning improve anesthesia residents' performance in managing simulated maternal cardiac arrest. After specific teaching, most participants were able to make a decision to perform PMCD within the recommended time frame of four minutes from the onset of maternal cardiac arrest.[22]

The limitations of the current report are the small number of cases, data from a single institution, and poor reporting of events, particularly details regarding resuscitation, timelines, and the operation itself. The availability of a dedicated individual to document the exact timing and sequence of events during resuscitation or PMCS could be of paramount significance, which is emphasized during ACLS training. This review, however, showed that although each chart contained CPR records most of them were incomplete.

A national database would be useful for proper assessment of such rare cases to determine the true event rate, causes of cardiac arrest, modifiable risk factors, and maternal and neonatal survival rates. Integrating training modules during residency and adoption of accredited continuing professional development initiatives in obstetrical emergencies with a multidisciplinary team approach would undoubtedly help improve the mobilization of resources and management of these catastrophic, though rare, events.

Conflicts of interest None declared.

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