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## Clinical paper

# Maternal out-of-hospital cardiac arrest: A retrospective observational study



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## Abstract

**Aim:** Out-of-hospital cardiac arrests (OHCAs) in pregnant women are rare events. In this study, we aimed to describe a cohort of pregnant women who experienced OHCAs in a large urban area, and received treatment by the prehospital teams in a two-tiered emergency response system.

**Methods:** This retrospective study included pregnant women over 18 years of age who experienced OHCAs. The analysed variables included maternal age, gestational age, variables specific to the rescue system, number of shocks delivered by an automatic external defibrillator, and rates of maternal and neonatal survival.

**Results:** Over the 5-year study period, 19,515 OHCAs occurred, 16 of which were in pregnant women. These 16 patients had a median age of 31 years [interquartile range (IQR): 28–35] and a median gestational age of 20 weeks [IQR: 10–33]. Three patients (18.8%) had an initial rhythm of ventricular fibrillation. Only one patient underwent thrombolysis. Of the 16 patients, 6 (38%) died after resuscitation on the scene. The remaining 10 were transported to the hospital, of whom 5 achieved circulation through a mechanical CPR device. Only 2 patients were alive 30 days after OHCA.

**Conclusions:** Over half of the pregnant women who experienced OHCA were at least 20 weeks pregnant. Analysis of the prehospital medical data suggests that the current recommendations are difficult to apply in an out-of-hospital environment. Specific recommendations for this situation must be developed.

**Keywords:** Out-of-hospital cardiac arrest, Pregnancy, Perimortem caesarean section, Extracorporeal membrane oxygenation, Thrombolysis, Maternofoetal outcomes

## Introduction

The literature includes little information about the management of out-of-hospital cardiac arrests during pregnancy (OHCAP), and the available

reports focus on caesarean foetal delivery times and maternal-foetal survival. The European Resuscitation Council (ERC) makes recommendations on OHCAP based on in-hospital cardiac arrest (CA), expert opinions, extrapolations from non-pregnant women, and manikin-based studies.<sup>1</sup> Between 1990 and 2013, the maternal mortality rate (MMR) in

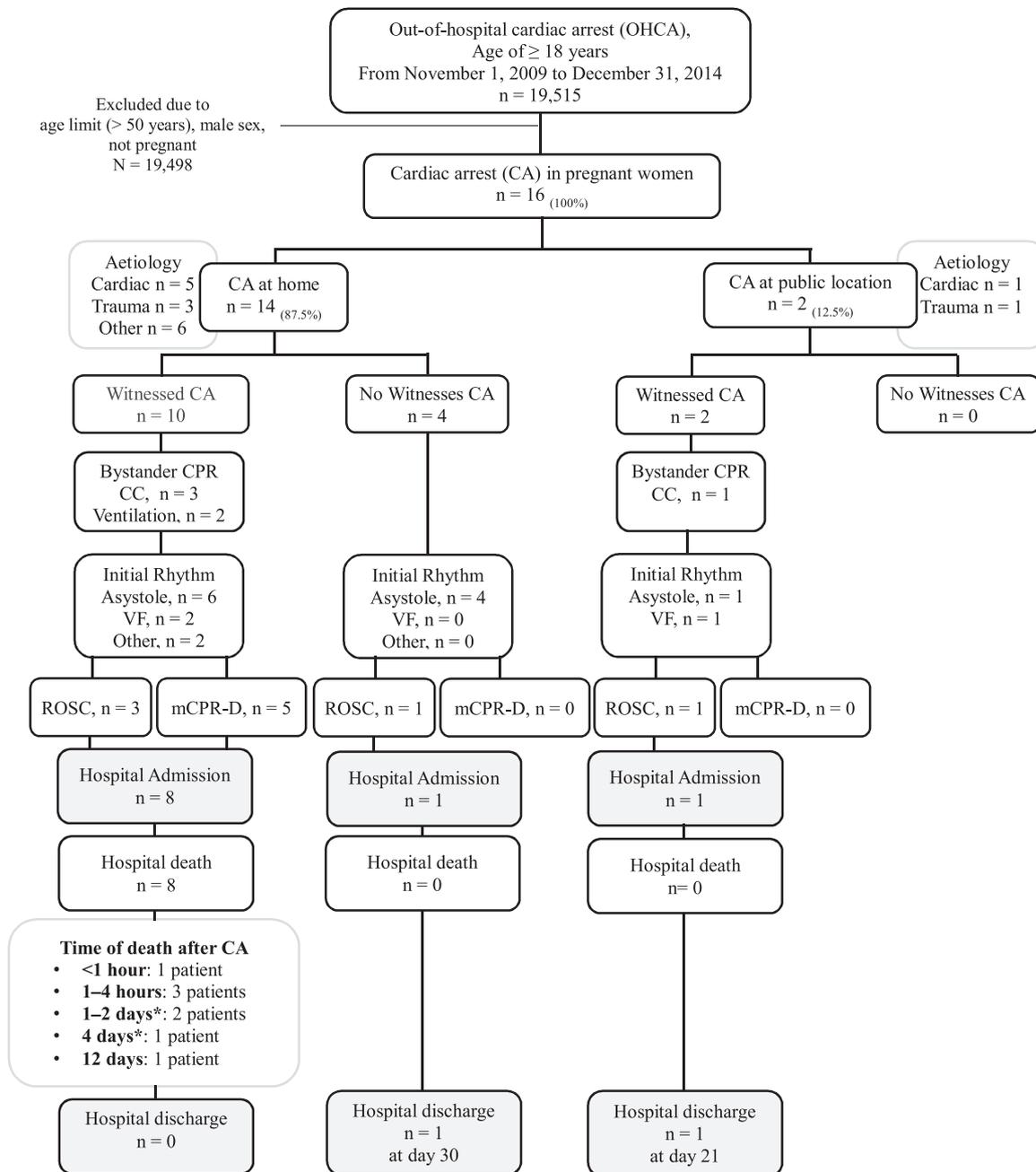
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**Fig. 1 – Flow chart of pregnant women suffering from out-of-hospital cardiac arrest with Utstein Style reporting. CA: cardiac arrest, CPR: cardiopulmonary resuscitation, CC: chest compressions, mCPR-D: mechanical CPR device, VF: ventricular fibrillation, ROSC: return of spontaneous circulation. \*Perimortem caesarean section.**

the United States doubled from 12 to 28 maternal deaths per 100,000 live births. In France, morbidity and mortality remained stable between 1998 and 2009, but maternal deaths due to cardiovascular aetiologies increased.<sup>2,3</sup>

In the present report, we describe a cohort of OHCA cases in Paris and its suburbs. In particular, we report the incidence of this pathology, the methods of prehospital care used by the medical teams, the times and places of foetal extraction, and maternal-foetal survival.

## Materials and methods

### Study setting

The emergency system of the Paris Fire Brigade (BSPP) serves 7 million inhabitants in an area of 800 km<sup>2</sup>. In 2015, the incidence of out-of-hospital cardiac arrests (OHCA) was 55 per 100,000 population, and the incidence of CA in maternity was 3 per 100,000 live births.<sup>3</sup>

This area is covered by a two-tiered emergency system. When the dispatch centre receives a call about a suspected OHCA, two types of teams are simultaneously triggered: Fire Fighter Basic Life Support (BLS) teams that include three professional firefighters, and Advanced Life Support teams that comprise an emergency physician, a nurse, and a driver. BLS teams are usually the first responders to arrive on the scene due to the high density of fire stations in Paris and its suburbs. Since 2010, an additional team has been sent by the Urgent Medical Assistance Service (SAMU), with the aim of establishing extracorporeal membrane oxygenation (ECMO). From the dispatch of the first team of firefighters, the usual median time until their arrival to the victim is estimated at 10 min with an interquartile range (IQR) of 8.8–13 min.<sup>4</sup>

### Study design

The present retrospective observational study included all pregnant women over 18 years of age who suffered OHCA in any term of their intrauterine pregnancy. OHCA was defined according to Utstein's recommendations. Data were collected from prehospital medical observation records, automated external defibrillator (AED) plot downloads, and hospitalisation records. The prehospital teams collected epidemiological variables (age, medical history, term of pregnancy in weeks, and place and time of OHCA occurrence), the interventional sequence for cardiopulmonary resuscitation (CPR) (presence of a witness, actions undertaken before the arrival of emergency aid, and intervention times of the various intervenors), clinical and therapeutic sequence [type of heart rate with AED use, number of external electric shocks (EES) administered, use of a mechanical chest compressions device (mCPR-D), drug treatments, and ECMO implementation], and prognostic sequence [on-site death, prehospital return of spontaneous circulation (ROSC), transportation to the hospital, and maternal-foetal survival].

### Statistics

Quantitative variables are presented as median [interquartile range] and qualitative variables as percentage. Data were compared using Chi<sup>2</sup> or Fisher's exact test, and a p value of <0.05 was considered significant. Calculations were performed using STATA software<sup>®</sup> v14.0.

### Ethical consideration

This study was approved by the Ethics Committee for Research in Anesthesia-Resuscitation (IRB 00010254-2016-148).

## Results

### Prehospital population and clinical characteristics of the pregnant women

From 2009 to 2014, the prehospital medical teams of the BSPP managed 19,515 OHCA cases (Fig. 1). These patients included 16 pregnant women, an incidence of 0.8 OHCA per 1000 OHCA. Of these 16 women, 100% were receiving maternity care for their current pregnancy. Table 1 presents the clinical and demographic characteristics.

### Aetiology of arrest

The aetiologies were identified in 11 out of 16 cases (Table 2), and were traumatic in 4 cases (2 stab wounds, 1 hanging, and 1 defenestration from

**Table 1 – Demographics and baseline characteristics of pregnant women who received cardiopulmonary resuscitation by basic life support and advanced life support teams.**

Variables	n (%) n = 16 (100)
Age in years	31 [28–34.5]
20–34	12 (75.0)
35–39	2 (12.5)
≥40	2 (12.5)
Gestational age in weeks	20 [10–33]
<14	5 (31.2)
14–26/28	3 (18.8)
>26/28	8 (50.0)
Singleton pregnancy	16 (100)
Past medical history <sup>a</sup>	
Smoker	1 (10.0)
Hypertension and diabetes	1 (10.0)
Sickle cell disease	2 (20.0)
Other	4 (40.0)
None	2 (20.0)
Day of OHCA	
Week	14 (87.5)
Weekend	2 (12.5)
Time of OHCA	
Daytime [7:00 AM–19:00 PM]	8 (50.0)
Night [19:00 PM–7:00 AM]	8 (50.0)
Witnessed arrest	11 (68.8)
No flow time (min) <sup>b</sup>	7.5 [2–10]
Low flow time (min) <sup>c</sup>	45 [30–70]
Catheters by ALS team	16 (100)
Intravenous route	15 (94.0)
Intraosseous route	1 (6.0)
Cumulative epinephrine given IV (mg) <sup>d,e</sup>	10 [5–15]
Amiodarone given IV	2 (12.5)
Thrombolysis <sup>f</sup>	1 (6.3)

OHCA: out-of-hospital cardiac arrest, min: minutes, ALS: advanced life support, IV: intravenously, mg: milligrams, AM: antemeridian, PM: postmeridian.

Values are reported as median [IQR, interquartile range] or number (percentage).

<sup>a</sup> 6 missing values (mv).

<sup>b</sup> 8 mvs (all nonsurvivors).

<sup>c</sup> 9 mvs (all nonsurvivors).

<sup>d</sup> 4 mvs (all nonsurvivors).

<sup>e</sup> Epinephrine was administered as soon as venous access was achieved, as a 1 mg bolus every 3–5 min in accordance with current guidelines.

<sup>f</sup> One pulmonary embolism was suspected by the prehospital physician and secondarily confirmed by computed tomography pulmonary angiography.

**Table 2 – Prehospital care and maternofoetal outcomes according to term of pregnant women suffering from out-of-hospital cardiac arrest.**

Patient	Term in weeks (n = 16)	Aetiology	Prehospital ROSC	Prehospital cumulated epinephrine (mg) given by ALS	Prehospital EES delivered	CPR status at hospital arrival	In hospital PMCS	Time from CA to PMCS	Survival to hospital discharge		
									Maternal	Foetal	
P1	<14 weeks	6	Cardiac	Yes	3	Yes	No CC needed	–	–	Yes	No
P2		7	Cardiac	Yes	5	Yes	No CC needed	–	–	Yes	Yes
P3		8	Unknown <sup>a</sup>	Yes	10	Yes	No CC needed	–	–	No	No
P4		10	Traumatic	No	14	No	–	–	–	No	No
P5		10	Unknown <sup>a</sup>	No	<i>mv</i>	No	With mCPR-D	–	–	No	No
P6	14-26/28 weeks	15	<i>mv</i>	No	10	No	–	–	–	No	No
P7		20	Cardiac	Yes	15	No	No CC needed	No	–	No	No
P8		20	Traumatic	No	15	No	–	No	–	No	No
P9	>26/28 weeks	31	Cardiac	No	15	No	With mCPR-D	No	–	No	No
P10		31	Other <sup>b</sup>	Yes	<i>mv</i>	No	No CC Needed	Yes	90 min	No	No
P11		33	<i>mv</i>	No	5	No	–	–	–	No	No
P12		34	Cardiac	No	<i>mv</i>	No	With mCPR-D	No	–	No	No
P13		37	Cardiac	No	10	Yes	With mCPR-D	Yes	55 min	No	No
P14		39	Unknown <sup>a</sup>	No	18	Yes	With mCPR-D	Yes	110 min	No	No
P15		>26/28	Traumatic	No	5	No	–	No	–	No	No
P16		>26/28	Traumatic	No	<i>mv</i>	No	–	No	–	No	No

P: patient, ROSC: return of spontaneous circulation, ALS: advanced life support, EES: external electric shock, PMCS: perimortem caesarean section, min: minutes, mg: milligrams, mCPR-D: mechanical CPR device, CA: cardiac arrest, *mv*: missing value, CC: chest compressions.

–Not relevant for patient.

<sup>a</sup> Three aetiologies remained unknown after hospital investigations.

<sup>b</sup> Other for hypoxic cardiac arrest after epileptic seizures.

the 6th floor) and medical in 7 cases (3 pulmonary embolism, 2 myocardial infarction, 1 respiratory distress, and 1 hypertrophic cardiomyopathy). For three patients, the aetiology remained unknown despite extensive hospital investigations, including echocardiography, computed tomographic angiography, coronary angiography, brain MRI, and blood analysis. For two patients, death was declared on the scene after stopping CPR, and aetiologies were not reported. Indeed, in one case, there was no forensic autopsy requested by the prehospital emergency physician. In the other case, forensic autopsy results were not available. Using Fisher's exact test, we found no significant association between the variables "term in weeks" and "aetiology" ( $p = 1$ ).

### Characteristics of prehospital CPR

Characteristics of prehospital CPR are summarized in Table 1 and Fig. 2. Fig. 3 presents the precise numbers of EES and their success/failure at the BLS and ALS care levels. At the BLS level, 3 of 16 cases (18.75%) received EES. The BLS team uses only bag-mask ventilation during resuscitation, in contrast to UK or US paramedics, who frequently use supraglottic airway devices. Furthermore, BLS teams are not authorized to administer epinephrine. The ALS team established the intravenous route, performed tracheal intubation, and administered epinephrine (1 mg every 3–5 min). Table 2 presents details of the epinephrine doses given. The prehospital medical reports did not note instances of difficulty with or failed intubation.

### Maternal outcome

Maternal outcome is reported in Fig. 1, and more precisely described for each case in Table 2. Over half of the women were at least 20 weeks pregnant. Fig. 2 synthesizes the outcomes of the 16 pregnant women. Six

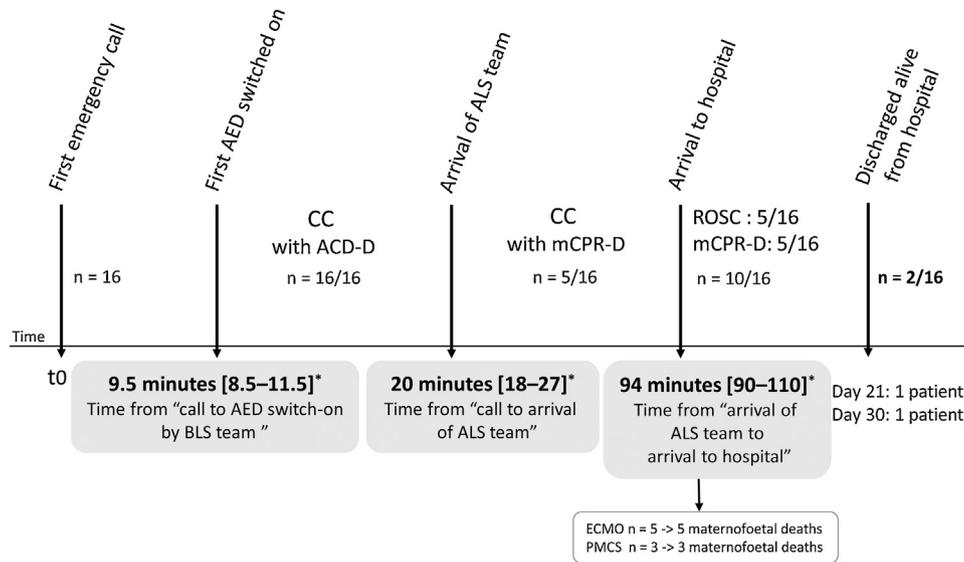
women were pronounced dead on the scene by the prehospital emergency physician after CPR. The remaining 10 patients were transferred to intensive care, 5 with chest compressions applied using a mCPR-D, and 5 after achieving a prehospital ROSC. Fig. 3 summarizes the shocks administered by the BLS and ALS teams. Three patients received EES from the BLS team with no successful return of spontaneous pulse, and subsequently also received EES from the ALS team. Of these patients, two achieved a prehospital ROSC, and the third was transported to the hospital with a mCPR-D. One patient exhibited a ROSC after CPR by the BLS team plus EES by the ALS team. Two patients had a ROSC after CPR only (no EES), of whom one died on the 4th day post-CA, and one died at the hospital 4 h post-CA after prehospital ROSC and thrombolysis. Two patients, whose pregnancies were both in the first trimester, were discharged alive from the hospital at days 21 and 30.

### Foetal outcome and neonatal survival

For the 14 mothers who did not survive CA, the foetuses' deaths were diagnosed by ultrasound upon hospital arrival (Table 2). In 3 of these 14 cases, in-hospital perimortem caesarean section (PMCS) was performed to optimize maternal resuscitation (Table 2). In the only case with a live birth, the mother suffered from OHCA at 7 weeks of pregnancy, survived, and gave birth at 40 weeks. The newborn had a weight of 3 kg and a 5-min Apgar score of 9.

## Discussion

In the present study, we reported the largest French OHCA cohort to date. Their prognosis was dramatically poor. Over half of the patients



**Fig. 2 – Timeline of main events during pre-hospital cardiopulmonary resuscitation.**

**CC:** chest compressions, **CPR:** cardiopulmonary resuscitation, **ACD-D:** active compression-decompression device, **mCPR-D:** mechanical CPR device, **AED:** automated external defibrillator, **PMCS:** perimortem caesarean section, **ECMO:** extracorporeal membrane oxygenation, **BLS:** basic life support, **ALS:** advanced life support, **ROSC:** return of spontaneous circulation, **t:** time.

\*Values of time are reported as median [interquartile range].

BLS care level			
Patient	No. EES (AED)	ROSC Yes/No	Manual ACD-D Yes/No
P1	1	No	Yes
P2	0	No	Yes
P3	1	No	Yes
P13	1	No	Yes
P14	0	No	Yes

ALS care level				
Patient	No. EES (manual defibrillator)	ROSC Yes/No	mCPR-D Yes/No	Hospital Arrival Yes/No
P1	1	Yes	No	Yes*
P2	2	Yes	No	Yes*
P3	3	Yes	No	Yes
P13	2	No	Yes	Yes
P14	1	No	Yes	Yes

**Fig. 3 – Cardiopulmonary resuscitation and defibrillation strategies among patients with ventricular fibrillation during basic life support and advanced life support care.**

**P:** patient, **BLS:** basic life support, **ALS:** advanced life support, **No.:** number, **EES:** external electric shock, **ROSC:** return of spontaneous circulation, **mCPR-D:** mechanical CPR device, **ACD-D:** active compression-decompression device, **VF:** ventricular fibrillation, **AED:** automated external defibrillator.

were over 20 weeks pregnant (uterus to the umbilicus), and CA was more commonly of non-traumatic origin than traumatic aetiology. This is in agreement with country-wide observations that later pregnancies are associated with a parallel increase in the risk of cardiovascular complications.<sup>5</sup> In the out-of-hospital setting, outside of traumatic context and expulsive efforts, a prehospital emergency physician must discriminate a pulmonary embolism and a myocardial infarction based on the probability of occurrence.

Cardiac arrest during pregnancy is a devastating event with a poor prognosis. In our cohort, one factor contributing to the poor maternal prognosis was the relatively low rate (33%) of witnesses initially performing chest compressions compared to the literature.<sup>6</sup> Travers et al. reported that among OHCA sufferers in the French emergency system, 30% received CPR performed by a witness.<sup>7</sup> In France, only 49% of the population has received first-aid training, while this rate exceeds 80% in the Nordic countries.<sup>8</sup>

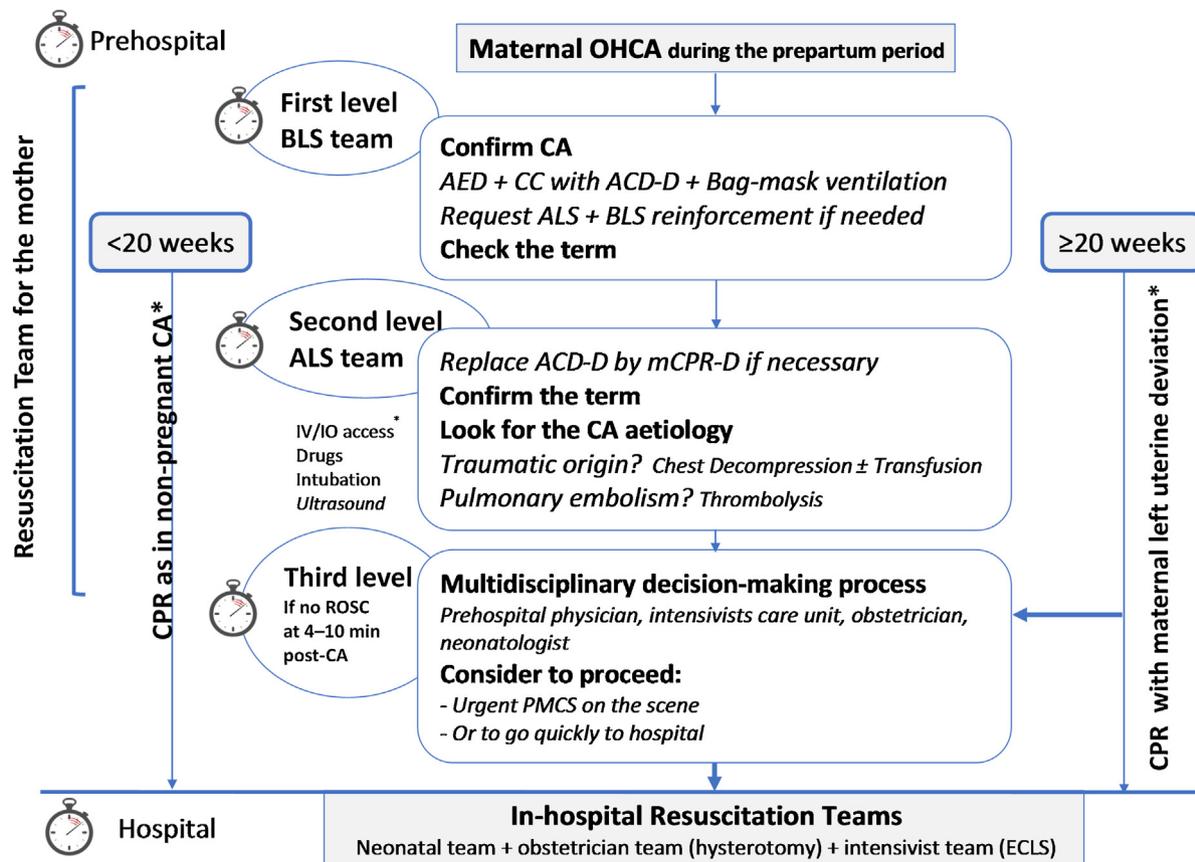
Another factor that may have affected outcomes in our cohort is that the BLS team only began using uterus displacement to relieve aortocaval compression in 2015, after our study period had ended. Failing uterine displacement, chest compressions were performed in the supine position to enable use of greater force than in left lateral tilt.<sup>9</sup> Notably, the BLS team might have had difficulty even if using the initial fundamental act of uterine displacement, since left lateral uterus displacement requires 1 or 2 additional hands from a free responder.

The extended time on the scene also likely contributed to poor maternal outcome after 20 weeks. Indeed, the ALS team performed CPR until achieving ROSC or stopped CPR to declare death on the scene. The long times remaining on the scene to perform CPR clearly explain the absence of PMCS or the long time taken to perform it. Additionally, urgent transfer to a hospital for resuscitative hysterotomy was impossible due to difficulties regarding the availability of the appropriate hospital units (e.g. neonatal, intensivivist, ECMO, and obstetrician teams).

When feasible, the performance of a prehospital PMCS could improve the chances of the mother's survival. The ERC recommends that PMCS be performed within 4 min post-CA if resuscitative efforts are unsuccessful.<sup>1</sup> However, this rule is not applicable in our prehospital setting for several reasons. First, it takes far longer than 4 min for an ALS team to arrive on the scene in our emergency system, and this delay is inevitable. In the literature, four cases of prehospital PMCSs were

reported with OHCA-hysterotomy delays of 15–40 min, but outcomes were still poor.<sup>10–12</sup> Second, although a scalpel is the only necessary equipment for initiating a PMCS,<sup>13,14</sup> emergency physicians are not trained in the specific procedures of a PMCS. It is not possible to recommend that PMCS be performed by an emergency prehospital physician without reforming the training model and the care network. Therefore, the prehospital emergency physician should ensure an urgent transfer to the hospital with minimal scene time so that those waiting at the hospital can perform the “resuscitative hysterotomy”.

Improving the outcomes of pregnant women suffering from OHCA relies on multidisciplinary training and a process of critical reflection.<sup>15</sup> Since 2014, joint BLS/ALS teams in our backup system have undergone high-fidelity simulation training to improve technical skills, as well as human factors. The objectives of such training are to reduce the decision–delivery interval, to encourage performance of CPR accounting for the term of pregnancy, and to identify the leadership.<sup>16</sup> In cases where the pregnancy term is less than 20 weeks, teams are taught to use the same CPR method that they would use for a non-pregnant patient. In cases where the pregnancy term is over 20–24 weeks, the patient must be promptly transferred to hospital while rescuers continue CPR, and PMCS should be performed immediately upon arrival to relieve aortocaval compression.



**Fig. 4 – Mnemonic to aid recall of the key guidelines for pregnant women suffering from an out-of-hospital cardiac arrest.**

**OHCA:** out-of-hospital cardiac arrest, **CA:** cardiac arrest, **CPR:** cardiopulmonary resuscitation, **CC:** chest compressions, **mCPR-D:** mechanical CPR device, **ACD-D:** active compression-decompression device, **AED:** automated external defibrillator, **ROSC:** return of spontaneous circulation, **BLS:** basic life support, **ALS:** advanced life support, **IV:** intravenous, **IO:** intraosseous, **PMCS:** perimortem caesarean section, **ECLS:** extracorporeal life support, **min:** minutes. \*Truhlár et al. European Resuscitation Council Guidelines for Resuscitation 2015.

Prehospital ECMO could improve maternofetal outcome. However, medical decisions regarding the implementation of prehospital ECMO remains challenging. In our emergency system, EMCO is utilized for witnessed OHCA in young people.<sup>17,18</sup> In cases of CA in woman who are more than 20 weeks pregnant, PMCS must be performed prior to ECMO to relieve the aorta and vena cava of possible compression by the uterus and to enable effective ECMO. Two possible strategies have been proposed to address this problematic ECMO-PMCS situation in Paris' intervention jurisdiction. In one strategy, the patient could be medically transferred to a hospital facility near the intervention site, and the sector-specific ECMO mobile team would travel to the respective hospital centre. In the other strategy, the ECMO mobile team could be trained in PMCS procedures.<sup>19</sup>

### Limitations of the study

Our work has a number of limitations, particularly due to missing data related to the retrospective data collection. We could not obtain the relevant information regarding "prehospital uterus displacement". Moreover, the rate of OHCA among pregnant woman was likely underestimated in the absence of witnesses who could confirm the precise progress of a pregnancy or a uterine height suggestive of pregnancy.

### Conclusion

This was the first study to report the outcomes of a cohort of pregnant women suffering from OHCA who received prehospital care in France. The initial rhythm was rarely VF. The maternal-foetal prognosis was poor, and seemed better in cases of OHCA during the 1st trimester of pregnancy. Despite short intervention times, all cases failed to meet the ERC's recommendation to perform PMCS within 4 min post-CA. It should still be emphasized that it is not the lack of the ALS physician's skill to perform PMCS but the time getting to the hospital that matters. Based on the present data, we created recall aid to optimize coordination of the BLS/ALS teams in the decision-making process (Fig. 4). The current guidelines for the management of pregnant women suffering OHCA are not strictly transferable to prehospital teams. Further studies are needed to more precisely define the best prehospital strategy to improve maternal-foetal survival in this situation.

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### Conflict of interest statement

None.

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