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Impact of 'synchronous' and 'asynchronous' CPR modality on quality bundles and outcome in out-of-hospital cardiac arrest patients

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Abstract

During cardiopulmonary resuscitation (CPR), the need to interrupt chest compressions to provide synchronous ventilations prevents blood flow continuity, reducing the possibility to ensure high-quality CPR bundles of care and, thus, having a potentially negative impact on perfusion and patient outcome. Contemporaneous asynchronous chest compressions and ventilations may avoid these potentially negative effects. Only a few studies measured the CPR quality metrics during synchronous and asynchronous CPR modality and its relation to patient outcome. A prospective observational study was conducted on 285 consecutive adult patients with out-of-hospital cardiac arrest treated by EMS teams over a 30-month period. Ventilation rate, chest compression fraction (i.e. cardiac arrest time spent delivering uninterrupted chest compressions compared to total cardiac arrest time) and chest compression rate per minute were collected in real time by defibrillators and analysed through a dedicated software (electrical cardiac activity through the ECG, chest compression and ventilations through the transthoracic impedance) during synchronous and asynchronous CPR modalities. During asynchronous CPR modality, higher ventilation rate and chest compression fraction ($p < 0.001$), and lower chest compression rate per minute ($p < 0.001$) were ensured, being all cited metrics more adherent to the high-quality CPR bundles. Ventilation rate provided during the whole CPR was an independent predictor for a good neurological outcome (OR 3.795, $p = 0.005$). Asynchronous chest compression and ventilation ensured the most adequate chest compression fraction, uninterrupted chest compression rate and ventilation rate.

Keywords Asynchronous CPR · Cardiac arrest · Cerebral performance category · Intubation · Out-of-hospital · Quality metrics · Ventilation

Introduction

The prognosis of out-of-hospital cardiac arrest (OHCA) is poor [1]. To improve outcome, guidelines for cardiopulmonary resuscitation (CPR) recommend employing several bundles of care, emphasising the concept of 'high-quality CPR' as a key factor [2, 3]. Ensuring high-quality chest compressions with a compression rate between 100 and 120 min^{-1}, while reducing interruptions for delivering ventilations and defibrillations, has been stressed to maximise the proportion of time during which patients received uninterrupted chest compressions (chest compression fraction) [4], with the aim of increasing organ perfusion and patients' functional survival. Accordingly, review and evaluation of CPR quality metrics and variables have been proposed as a valid approach to be integrated in a standard post-event team debriefing [5]. Thanks to the current technology integrated into defibrillators, the quality of each CPR performance can

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be objectively measured through the analysis of electrical cardiac activity (ECG) and transthoracic impedance (TTI), the latter allowing for the analysis of the chest compression and ventilation provided [6].

Chest compression and ventilation can be delivered according to two different modalities: the 'synchronous' CPR, consisting of alternating a cycle of 30 uninterrupted (rate 100–120 min^{-1}) chest compressions with a cycle of two ventilations; or the 'asynchronous' CPR, where—after providing tracheal intubation or supraglottic airways devices—ventilation can be delivered without interruption while continuous chest compressions are contemporaneously provided [2]. It is reasonable to believe that, by avoiding most pauses, better CPR quality metrics and variables may be ensured with asynchronous CPR modality. Unfortunately, only few studies compared metrics such as chest compression fraction [7] and no study compared the actual ventilation rate in OHCA patients having undergone CPR with synchronous and asynchronous modality. To verify our hypothesis, in the present investigation we analysed the TTI trace of OHCA patients to compare ventilation rate, chest compression fraction and chest compression rate per minute during synchronous and asynchronous modalities of CPR. A second aim of the present study was to assess if the above CPR quality variables can be considered as independent predictors for a good neurological outcome, while controlling for several confounding factors known to affect the OHCA outcome.

Methods

Study design, setting and population

This was a prospective observational study realised in the Emergency Medical Service (EMS) of Trieste, Italy. Ambulances were staffed with one registered nurse, one nurse assistant and one trained driver. Nurses were able to provide CPR, defibrillation, and intravenous adrenaline (epinephrine). Advanced life support (ALS) was ensured by 'rapid response medical cars' staffed with one experienced emergency physician able to administer intravenous medications and provide advanced airway management by tracheal intubation or, alternatively, by supraglottic devices. All teams were equipped with LIFEPAK defibrillators (LP-12 or LP-15, Physio-Control, Redmond, WA, USA). A mechanical device for CCs (LUCAS 2™, JOLIFE AB, Lund, Sweden) was available in the ALS unit. Patients were transported to a single hospital, where angiography, percutaneous coronary intervention (PCI), and standardised post-resuscitation care, including target temperature management at 36 °C [8], were available around the clock and activated according to predefined protocols.

All consecutive adult OHCA patients treated by the EMS teams from 1 January 2013 to 30 June 2015 with real-time electronic documentation from the defibrillator (ECG and TTI traces) were included in the study. Patients with CPR shorter than 5 min in the presence of asystole were excluded, unless return of spontaneous circulation (ROSC) was obtained.

The study was approved by the Institutional Ethical Committee as a part of the Italian Registry of Cardiac Arrest-RIAC study [9].

Study procedure and data collection

All team members were trained according to the most recent CPR guidelines, with emphasis on main CPR bundles of care: (1) high-quality chest compressions (rate 100–120 min^{-1}, depth 5–6 cm, allowing full recoil of chest after each compression, minimise interruptions), (2) effective ventilation (rate 10–12 min^{-1}, spending approximately 1 s inflating the chest with a volume ensuring no more than normal chest rise, early 10–15 L min^{-1} oxygen supplementation) [2, 5]. Upon arrival at the CA scene, the EMS team started or continued (if already initiated by bystanders) CPR. Defibrillator pads were promptly connected to check ECG rhythm and provide defibrillation as soon as possible, when indicated, thus activating continuous TTI recording. Mechanical chest compressions and tracheal intubation were subsequently implemented, taking care to minimise interruptions while applying the device and performing intubation without stopping chest compressions; in case of difficult intubation, bag-valve-mask ventilation was resumed and intubation postponed to a later time, according to EMS protocols. Before tracheal intubation, a synchronized 30-to-2 compressions/ventilation ratio was attained, with ventilation given by a bag-valve-mask device during as short as possible pauses in compressions. In intubated patients, ventilation was delivered independently and asynchronously during uninterrupted chest compressions.

All main events (e.g. intubation, ROSC) were tagged on the defibrillator monitor. The time of CA onset was estimated by crossing the information obtained from: the recorded emergency calls and radio communications; computerised dispatch data; EMS rescue forms; and EMS team interviews. The time between the estimated CA onset and the start of CPR by the EMS team (as documented by the defibrillator recording) was defined as CA-CPR interval. Synchronisation of the defibrillator clocks with the dispatch central clock was checked monthly.

All defibrillator-recorded data were identified by an automatically generated code and transferred by modem to a central server. Data on patient demographics and prehospital variables were obtained from EMS documentation and, in case of any doubt, by interviewing the EMS teams.

Data processing

LP-recorded data were analysed through the Code-Stat™ software (release 9.0, Physio-Control Inc., Redmond, WA), which displays continuous graphs reflecting actual times of the events, ECG, defibrillation attempts, chest compressions, and ventilations. Regarding the TTI graph, a flat line was shown when no change affects the TTI, whereas lung inflation, left ventricular systole and CCs registered a temporary change in TTI [10].

The first ECG rhythm associated with CA, namely asystole, pulseless ventricular tachycardia (VT), ventricular fibrillation (VF) or pulseless electrical activity (PEA), was documented. PEA was defined as QRS-complexes without blood flow-induced changes in TTI [10, 6].

Utstein guidelines recommend documenting any ROSC event and duration as a core data element [11]. Any ROSC episode—reported by the EMS team as the presence of an organised ECG rhythm associated with palpable pulse—was subsequently confirmed by Code-Stat analysis, revealing interruption of chest compressions and presence of QRS complexes with corresponding pulse-generating modifications in TTI signal [12]. ROSC was defined as 'sustained' (s-ROSC) if it persisted until arrival at the emergency department and transfer of care to medical staff at the receiving hospital [11], whereas ROSC episodes lasting more than 1 min (irrespective of duration or point in time) with resumption of chest compressions at a later time were defined as a 'transitory' ROSC period (t-ROSC) [13, 14].

The 'start' of a CA episode was defined as the first therapeutic event after EMS arrival and corresponding to the start of CPR (e.g. first recorded chest compression or first rhythm analysis) [15, 10]; the 'end' was marked immediately after the last registered chest compression, coinciding with having obtained a s-ROSC or with certification of death [15]. The time (minutes) between 'start' and 'end' of CA episode—after excluding t-ROSCs periods, if any—was designated as CA time [15].

Code-Stat automatically recognised chest compressions with high sensitivity and positive predictive value [16]. Activation of high-pass filter (1.5 Hz lower cutoff) facilitated the view of chest compressions. Each cycle of uninterrupted chest compressions, considering compressions with pauses of less than 1.5 s between the end edge of a compression and the initial stretch of the next one [15], was identified with 'start' and 'stop' flags. Uninterrupted chest compression rate was defined as the mean frequency per minute during uninterrupted chest compressions; actual chest compression rate per minute was calculated by dividing the total number of provided compressions by CA time. The ratio between time spent delivering uninterrupted chest compressions and CA time was defined as chest compression fraction.

The recognition of ventilations by changes in the TTI signal has been employed in previous studies [17, 10, 6]. Activation of low-pass filter (0.5 Hz upper cutoff) facilitated the view of ventilation curves (Fig. 1). All ventilations were manually identified and marked. Based on the EMS documentation and team interviews, possible restoration of spontaneous breathing during each t-ROSC period was also verified. The ventilation rate per minute was calculated by dividing the total number of ventilations by CA time. The length of CA time before and after intubation was also measured, and ventilation rate, uninterrupted chest compression rate and chest compression fraction were calculated separately for the pre- and post-intubation phases. According to intubation time, two different stages of CA time were

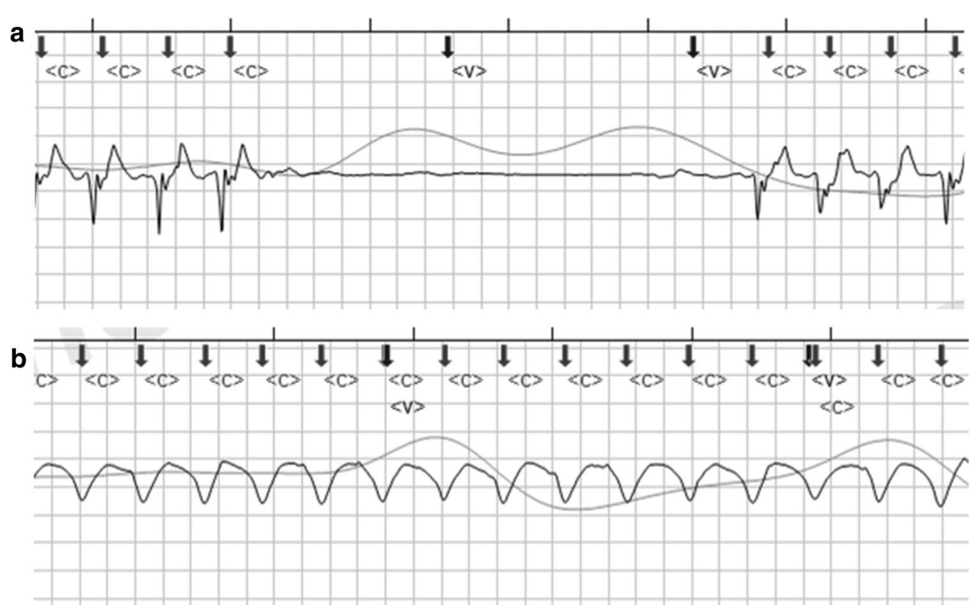

Fig. 1 Examples of recognition of ventilations curves by changes in the TTI signal after activation of low-pass filter (0.5 Hz upper cutoff), during **a** synchronous and **b** asynchronous CPR modality. Gray line: transthoracic impedance signal. Black line: electrocardiographic trace. *<C>*: chest compression. *<V>* ventilation

identified: (1) the percentage of CA time before intubation (in which intermittent chest compressions and synchronised ventilations were delivered), and (2) the percentage of CA time after intubation (in which continuous chest compression with asynchronous ventilations were delivered). For patients who were not intubated, the percentage of time before intubation was recorded as 100 and the time post intubation as 0.

Outcome data were obtained from hospital documentation. The endpoint was neurological function at hospital discharge according to the cerebral performance category (CPC) [11], a 5-point scale ranging from 1 (good cerebral performance) to 5 (dead); survival with good neurological outcome was defined as a CPC ≤ 2.

Data analysis

Continuous variables were displayed as mean ± standard deviation (SD) and median, nominal variables as number and percentage. Unadjusted comparisons between groups were analysed via χ^2 test. The difference between the mean values was analysed using the unpaired Student's *t* test, after determining whether or not equal variance could be attributed to the subgroups as per Levene's test.

Multiple logistic regression models were used to examine the independent association between the explored quality variables and the considered outcome, while controlling for several factors known to affect the OHCA outcome (age, shockable initial rhythm, CPR started before EMS arrival, CA-CPR interval, and CA time) [18–20]. To obtain a more normal distribution for data showing excessive skewness or kurtosis, a square-root transformation was done on the CA-CPR interval, CA time, uninterrupted chest compression rate, ventilation rate and CA time provided with intubated airway. The coefficient of determination of the regression models was calculated based on the Nagelkerke R^2. Hosmer–Lemeshow test for logistic regression was used to assess the goodness-of-fit of the final model.

Statistical analysis was performed using IBM software SPSS Statistics, release 24.0 (Armonk, NY, US: IBM Corp.). For all tests, an alpha level of $p \leq 0.05$ was set for statistical significance.

Results

In the study period, there were a total of 340 OHCAs, of which 311 (91.5%) had complete TTI and ECG data. Twenty-six cases were excluded because two were paediatric patients and 24 presented asystole with CPR lasting less than 5 min. Finally, 285 OHCA patients (age: 74.1 ± 14.7 years; median 76) constituted the study population. The average CA-CPR interval was 9.2 ± 6.0 min (median 8). In 44 (15.5%), CPR was started before the EMS arrival. VF/VT was the first documented ECG rhythm in 81 cases (28.4%). With reference to the CA-related variables explored, chest compression fraction was 70.0 ± 12.4% (median 72.4), uninterrupted chest compression rate was 115.4 ± 18.4 CCs min^{-1} (median 110.1), actual chest compression rate was 80.3 ± 17.3 CCs min^{-1} (median 80.5), and ventilation rate was 7.7 ± 3.9 breath min^{-1} (median 7.2). In 66 cases (23.2%) synchronous CPR was provided during the whole CA time, while the remaining 219 patients (76.8%) shifted to asynchronous CPR after underwent tracheal intubation (in no case, supraglottic devices were used). Overall, 50.6 ± 34.1% (median 59.8%) of CA time was spent by delivering asynchronous CPR. No patient was restored to spontaneous breathing during the t-ROSC periods. Comparing the asynchronous and synchronous CPR periods (Fig. 2), statistically significant differences were found for the ventilation rate (synchronous: 4.3 ± 2.1 min^{-1}, median 4.0; asynchronous: 10.2 ± 3.7 min^{-1}, median 10.3; $p < 0.001$), the chest compression fraction (synchronous: 62.2 ± 15.0%, median 66.1; asynchronous: 74.1 ± 18.3%, median 78.2; $p < 0.001$), and the uninterrupted compression rate (synchronous: 128.8 ± 19.4 min^{-1}, median 117.9; asynchronous: 110.3 ± 18.5 min^{-1}, median 102.4; $p < 0.001$).

Eighty-one patients (28.2%) achieved s-ROSC, 16 of whom died before hospital discharge. For two patients CPC was not evaluated because they were transferred to other hospitals. Among 283 patients with known outcome, 16 (5.7%) were discharged from the hospital with a good neurologic outcome (CPC 1: $n = 15$; CPC 2: $n = 1$), while 267 died or were discharged from the hospital with poor neurologic outcome (CPC 3–5). Lower age, shorter CA-CPR interval, CPR started before EMS arrival, VF/VT as first documented rhythm, higher ventilation rate, and shorter CA time were associated with good neurological outcome at hospital discharge in bivariate analysis (Table 1).

Table 2 shows the logistic regression model with the best coefficient of determination, explaining just over 50% of the variance for good CPC ($R^2 = 0.504$). The model was well calibrated (Hosmer–Lemeshow test: $\chi^2 = 1.252$; $p = 0.996$). According to the model, five covariates (CA-CPR interval, CPR started before EMS, shockable rhythm, CA time and ventilation rate) were found to be independent predictors of good CPC.

Discussion

The main results of the present study are that, in our population of OHCA patients, high-quality bundles more adherent to the CPR guideline recommendations were ensured during the asynchronous modality of CPR. Among these quality metrics, the ventilation rate provided during the whole CPR

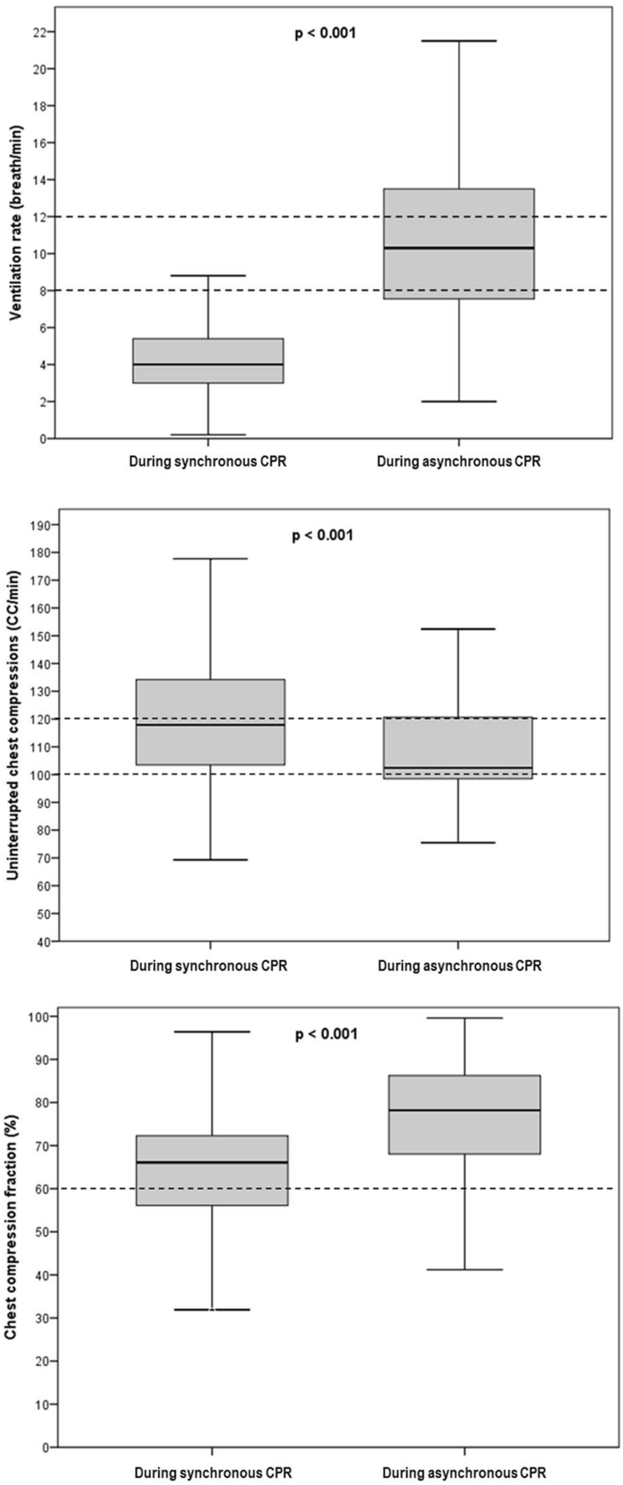

Fig. 2 Differences in CPR quality variables (**a** compression fraction; **b** uninterrupted chest compressions rate; **c** ventilation rate) during synchronous and asynchronous CPR modality provided before and after tracheal intubation, respectively. Dashed lines: recommended ranges/thresholds

was independently related to a good neurological outcome. According to our findings, important considerations can be proposed about the implications of ensuring contemporaneous asynchronous continuous chest compressions and ventilations.

Our data showed that asynchronous CPR is superior to synchronous CPR in ensuring a chest compression fraction, uninterrupted chest compression rate and ventilation rate more in conformity with the current guidelines for resuscitation (Fig. 2). Considering that in our population on average only a little more than half of the CA time was managed according to asynchronous CPR modality overall, it is possible to hypothesise that anticipating the time of advanced airway management may further improve the quality of CPR. However, it is extremely important to stress that laryngoscopy and intubation should be attempted without stopping chest compressions or delaying defibrillation and that repeated laryngoscopy attempts increase the risk of longer pauses in chest compression [21]; therefore, personnel not skilled enough in advanced airway management should avoid any intubation attempt [2]. As an alternative, a supraglottic device (e.g. laryngeal mask airway) may be positioned, still allowing to start asynchronous chest compression and ventilation [2]. This skill should be the prerogative of all EMS healthcare professionals to ensure asynchronous CPR as early as possible even in the absence of the EMS physician.

To ensure the highest possible chest compression fractions has been stressed as the most important quality variable to ensure during CPR. Regrettably, no agreement on the 'acceptable' chest compression fraction can be extrapolated from the literature, since various thresholds (i.e. > 50%, [22] > 60% [23, 2, 3], or even > 80% [5]) were recommended, and very different chest compression fractions were reported, ranging from 44 to 86% [24–26, 6]. In accordance with several previous studies [27, 28, 6], our data failed to demonstrate a relationship between chest compression fraction and patient outcomes. It should be noted that in our investigation the median compression fractions ensured during both synchronous and asynchronous CPR were higher than the thresholds recommended by both the European and American resuscitation guidelines [2, 3]; moreover, chest compression fraction was almost 73% in patients having either bad or good outcomes (Table 2). We could speculate that this widespread high chest compression fraction may have limited the impact of this variable as a predictor of outcome.

In line with data of previous similar studies [25, 10], we observed a median uninterrupted chest compression rate of 110 min^{-1}. However, after considering the performances in the two CPR-modality groups, we noticed that only during asynchronous CPR an uninterrupted chest compression rate within the recommended range was widely ensured (Fig. 2). Similarly to the chest compression fraction, this quality

Table 1 Relationships between patient and cardiac arrest variables and outcome at hospital discharge

Variable	CPC 3–5 ($n = 267$)	CPC 1–2 ($n = 16$)	p value
Age (years)[a,d]	74.7 ± 14.3 (76.0)	64.4 ± 18.6 (64.5)	0.006
CA-CPR interval (min)[a,e]	9.3 ± 6.1 (9.0)	6.0 ± 4.0 (5.0)	0.032
CPR started before EMS[b,e]	35 (13.2%)	8 (50.0%)	< 0.001
CA time (min)[a]	24.3 ± 13.9 (23.0)	14.9 ± 11.7 (11.5)	0.009
VF/VT as first documented ECG rhythm[b]	69 (25.8%)	12 (75.0%)	< 0.001
Uninterrupted CC rate (CC/min^{-1})[a]	115.0 ± 18.2 (110.0)	121.2 ± 22.0 (114.7)	0.189
Actual CC rate (CC/min^{-1})[a]	80.0 ± 16.5 (80.1)	85.0 ± 25.6 (82.7)	0.454
Ventilation rate (breaths/min^{-1})[a]	7.3 ± 3.5 (7.1)	12.7 ± 6.1 (12.8)	0.003
CC fraction (%)[a]	70.1 ± 12.3 (72.5)	69.3 ± 13.7 (73.4)	0.811
Asynchronous CPR time (%)[a,c]	50.3 ± 33.5 (58.9)	51.6 ± 43.6 (64.5)	0.912

CPC cerebral performance category, *CA* cardiac arrest, *CPR* cardiopulmonary resuscitation, *EMS* emergency medical service, *ECG* electrocardiographic, *VT* ventricular tachycardia, *VF* ventricular fibrillation, *CC* chest compression

[a]Mean ± standard deviation (median)

[b]*n*; %

[c]Percentage of CA time after intubation with asynchronous continuous chest compressions and ventilations

[d]$n = 275$

[e]$n = 283$

Table 2 Stepwise multiple logistic regression of survival with good neurological outcome (CPC ≤ 2) on study variables (Nagelkerke R^2: 0.504; $p < 0.001$)

Predictor	Odds ratio (95% CI)	p value
CA-CPR interval (min)	0.389 (0.205–0.740)	0.004
CPR started before EMS (yes)	10.498 (2.528–43.762)	0.001
Shockable rhythm (yes)[a]	13.710 (2.914–64.495)	0.001
CA time (min)	0.528 (0.346–0.806)	0.003
Ventilation rate (breaths/min^{-1})	3.795 (1.507–9.557)	0.005
Intercept	0.025 (/)	0.030

The following variables were included in the stepwise regression analysis but resulted not statistically significant in the final model: age, chest compression fraction, asynchronous CPR time, uninterrupted chest compression rate

CPC cerebral performance category, *CI* confidence interval, *CA* cardiac arrest, *CPR* cardiopulmonary resuscitation, *EMS* emergency medical service

[a]Ventricular fibrillation or tachycardia as first documented ECG rhythm

variable did not result as an independent predictor for good CPC at hospital discharge in our multivariable regression analysis; this result is in line with recent literature findings [29].

Among the many characteristics of ventilation, ventilation rate is the only clinically relevant and feasible variable to measure in OHCA studies [15]. In our population we documented a median ventilation rate of seven breaths min^{-1} throughout the CPR, lower than recommended by both the European (10 breaths min^{-1}) [2] and American (8–10 breaths min^{-1}) [3] guidelines, and by a recent consensus statement (< 12 breaths min^{-1}) [5]. Nevertheless, it should be noted that the ventilation rate we observed was still higher than is theoretically insurable by adopting the ‘synchronous’ CPR modality, since no more than 4–6 ventilations per minute can be provided if one considers that each two-ventilation cycle may require up to 5–6 s [30]. Again, similar to what observed for the other CPR quality metrics, the ventilation rate was more than double during asynchronous CPR compared synchronous CPR, being the first the sole CPR modality able to ensure a ventilation rate in line with guideline recommendations.

However, current guideline recommendations about the ventilatory strategy to be adopted during CPR are weak and based on low levels of evidence [31], so that the optimal ventilation rate capable of simultaneously ensuring an adequate gas exchange and good vital organs perfusion still remains unknown [32]. In the context of CPR metrics, the impact of ventilation on the outcome is one of the most debated and least resolved issues [33, 34] because of its competing interest in the use of time during CPR. On one side, excessive ventilation tends to reduce venous blood return to the heart, decreasing haemodynamics and both coronary and cerebral perfusion pressures; on the other side, insufficient ventilation leads to hypoxia and hypercarbic acidosis, significantly reducing myocardial contractility and increasing the defibrillation threshold, especially after a prolonged CA. Both hyper- and hypo-ventilation are, thus, potentially associated with poor outcome; consequently a certain amount of active lung ventilation should be ensured during CA [35], also because passive ventilation obtained during chest compressions cannot ensure physiologically significant tidal volumes [36]. In our investigation the ventilation rate was independently related to patients' outcome, observing for every additional breath per minute a 3.8 times increase in the odds for a good neurologic outcome. Considering that a ventilation able to cause a visible chest rise delivers a tidal volume of approximately 500–600 mL [2], an increase of even one breath per minute can determine a significant supplementary ventilatory volume throughout the resuscitation (e.g. about 12–14 L, considering 23 min of mean CA time in our data). The relationship between ventilation rate and patient outcome was previously tested in one study that analysed the first 5 min of CPR in a selected population of patients with shockable initial rhythm, reporting no differences in survival to hospital discharge [6].

A final consideration should be done on the importance of analysing and reviewing the CPR events based on real-time recorded parameters from a defibrillator. Thanks to this technology, the research on cardiac arrest may be significantly improved by offering the chance to focus on more detailed data. Just as an example, in the past several studies compared the impact of different modality of ventilation (endotracheal intubation, supraglottic devices, bag-valve-mask ventilation) [37–41] on patients' outcome, reporting controversial results. However, these studies analysed the impact of tracheal intubation per se, thus considering the procedure as a dichotomic variable (e.g. those who were intubated versus those who were not). It is evident that in intubated patients ventilation might not have been delivered through the tracheal tube for the whole CPR, as it is conceivable that a first stage had been managed with bag-valve-mask ventilation (e.g. before advanced life support arrival): since the ventilation rates may be different before and after intubation, the ventilation rate may also be different in the same group of intubated patients. In the present study we had the opportunity to explore the actual ventilation rate, uninterrupted chest compression rates and chest compression fraction. Furthermore, beyond the research field, this technology is a crucial opportunity to improve daily clinical practice, since allows EMS teams to review and analyse each CPR episode and, thus, to identifying drop-points to improve their subsequent performances.

Limitations

This study has some limitations that must be taken into account when considering the results related to the outcome. First, 8.5% of CAs occurring during the study period were excluded due to incomplete ECG and TTI data recording. Second, the impact of the explored variables on patients' outcome should be interpreted after considering that several other confounders (e.g. the comorbid conditions of a particularly aged population, the hospital care of patients who obtained s-ROSC) may have affect the outcome. Finally, the study was conducted in a single EMS centre; this fact limits the external validity of our results, which should be generalised with caution.

Conclusions

In our population, asynchronous CPR modality ensured the most adequate chest compression fraction, uninterrupted chest compression rate, and ventilation rate. The ventilation rate provided during the whole CPR was independently related to a favourable neurologic outcome. Accordingly, asynchronous modality of chest compression and ventilation should be ensured for the most time possible during CPR. Increasing the level of skills by ensuring to the EMS professional staff that get involved with the CPR over time a higher level of training on advanced airway management should therefore be a strategic objective of the EMS systems.

Further broader studies are needed to confirm our findings.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of human and animal rights This research conforms with the principles outlined in the Declaration of Helsinki. The study was approved by the Institutional Ethical Committee as a part of the Italian Registry of Cardiac Arrest-RIAC study.

Informed consent For survived patients admitted to the hospital, consent was managed following institutional procedures, providing that patients or her/his legal representative authorized the use of their clinical data for research purposes.

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