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Short paper

Increasing ventilation in drowning resuscitation – A cross-over randomized simulation study of ventilation during automated external defibrillator analysis pauses

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Abstract

Objective: The aim of this study was to analyze the feasibility of a new resuscitation strategy in which breaths are provided during automated external defibrillator (AED) rhythm analysis, and to evaluate its impact on chest compressions (CC) quality and the *peri*-analysis time.

Method: A randomized simulation study, comparing two cardiopulmonary resuscitations strategies, has been conducted: the standard strategy (S1) with strategy involving ventilation during AED analysis (S2). Thirty lifeguards have performed both strategies in a cross-over study design during 10 min of CPR.

Results: The number of ventilations per 10 min increases from 47 (S1) to 72 (S2) ($p < 0.001$). This results in the delivery of an additional 17.1 L of insufflated air in S2 compared to S1 ($p < 0.001$). There have been no significant changes in frequency and total number of CC. These findings correspond to a reduction of the non-ventilation period from 176 s (S1) to 48 s (S2).

Conclusions: This simulation study suggests that it is feasible to increase the number of ventilations during resuscitation following drowning, without affecting the quantity and quality of chest compressions. The results of this study may serve as a foundation for further investigation into optimal ventilation strategies in this context.

Keywords: Automatic External Defibrillator (AED), Cardiopulmonary Resuscitation (CPR), Drowning, Hypoxia, Strategy, Ventilation

Introduction

For the first time, in 2015, the European Resuscitation Council guidelines (ERC) introduced a specific algorithm for resuscitation in case of drowning. Traditional cardiopulmonary resuscitation (CPR) focuses on chest compressions (CC) for oxygen circulation, but the pathophysiology of cardio-respiratory arrest after drowning is often caused by hypoxia.[1,2] Therefore, the ventilation rate and tidal volume become the prioritized mechanisms to compensate for the low oxygen level. However, in the latest review promoted by the International Liaison Committee on Resuscitation (ILCOR),[3] there is still a knowledge gap regarding which ventilation strategies may be more optimal for drowning treatment. Experimental and clinical data support the importance of early reversal of hypoxia as a critical intervention for improving outcomes,[4,5] so, the continuation of ventilations during rhythm analysis could be a feasible alternative to consider in cardiac arrest follow drowning. Our hypothesis is that increasing the defibrillation pause time with ventilations may increase the liters of administered oxygen without affecting the frequency of CC, especially in incidents attended by first responders (e.g., lifeguards), where emergency medical services (EMS) assistance may be delayed for an extended period.[6]

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The aim of this study was to analyze the feasibility of a new resuscitation strategy in which breaths are provided during automated external defibrillator (AED) rhythm analysis, and to evaluate its impact on CC quality and the *peri*-analysis time.

Material and method

Participants

A convenience sample of lifeguards was invited to participate in this research. The inclusion criterion was that they were professional lifeguards. All lifeguards should be trained and certified under the ERC recommendations for CPR in special circumstances (drowning).[1] The exclusion criterion was that they had some permanent or temporary mental or physical impediment or did not provide informed consent. Participation was voluntary and without conflict of interest.

This research was approved by the Ethics Committee of the Faculty of Education and Sport Sciences (University of Vigo), with the code 21-2802-18, and developed in accordance with the Declaration of Helsinki. Each participant signed an informed consent form and agreed with the transfer of data and parameters from this study.

CPR re-training

To mitigate competency bias, all participants underwent a brief 15-minute training session at the beginning of the study to reacquaint themselves with the manikin and AED.[7] The sequence of this phase was: information about the drowning protocol, familiarization with AED and manikin, CPR practice with feedback, and a 2-minute CPR pre-test.

The purpose of this test was to screen lifeguards, including only those who demonstrated a high standard in CPR skills. A quality criterion was established, requiring participants to achieve a minimum success rate of 70% during CPR in order to proceed to the next experimental phase of the study. This threshold was verified using the feedback device on the CPR manikin LaerdalMedical's Q-CPR Skill Reporter software (Stavanger, Norway), and it has been acknowledged in scientific literature as a quality standard.[8–10]

Study design

The research team conducted a randomized cross-over simulation study comparing two CPR strategies: compared a standard strategy (S1) with a strategy involving ventilation during AED analysis (S2) (Fig. 1). In the randomization procedure, participants were randomly assigned to the two CPR strategies using a computerized random number generation system. Each participant received a unique identification number that was randomly and equitably associated with one of the two strategies. In this way, the order in which the strategies were carried out was randomized for each participant.

The lifeguards performed one-person CPR in two strategies, each lasting ten minutes.[11] Both strategies began with five rescue ventilations, followed by thirty compressions and two ventilations. All ventilations were performed using the mouth-to-mouth technique.

After two minutes, the AED initiated the analysis while the lifeguard continued CPR.

The standard strategy (S1) adhered to all the details of the ERC 2015 drowning resuscitation guidelines.[1] There were no compressions or ventilations during the AED analysis and instructions. This procedure will continue during the AED analysis breaks (every two minutes) throughout the 10 min of resuscitation (Fig. 2).

In the strategy aimed at increasing ventilation (S2), ventilations were maintained during the AED analysis (every two minutes). After the AED indicated that no shock was needed and instructed to continue CPR, the lifeguard proceeded with thirty cardiac compressions followed by two ventilations for another two minutes until the next AED analysis. (Fig. 2).

Measuring procedures and variables

Both CPR strategies were performed with two Laerdal ResusciAnne® manikins (Stavanger, Norway). The LaerdalMedical's Q-CPR Skill Reporter software (Stavanger, Norway) measured in real time: a) the volume of each ventilation in millilitres, b) the number of ventilations, c) the number of chest compressions, d) the mean compression rate per minute, e) the mean compression depth in millimetres and the percentages of chest compressions with correct f) hand-position, g) release, h) depth and i) rate. From this data, j) the total volume of all ventilations during ten minutes in each strategy was calculated and, k) the average volume per ventilation.

Each CPR was recorded with 180° viewing angle GoPro video camera HERO 4 systems (San Mateo, CA, USA) to be able to calculate the no-flow time between the last ventilation before the AED analysis and the first ventilation after the AED analysis, as well as the time between the last compression before and the first compression after the AED analysis. Based on this data, the total time (in seconds) without ventilations and the total time (in seconds) without compressions were calculated. For the AED analysis, a Laerdal AED Trainer 2 (Stavanger, Norway) was used, programmed with a non-shockable rhythm; this is the rhythm that is present in the majority of cardiac arrests following drowning.[3,12,13]

Statistical analyses

All statistical analyses were performed with SPSS for Windows version 20 (SPSS Inc, IBM, USA). The results are presented as median and interquartile range (IQR). After assessing the normality of the distributions with the Shapiro-Wilk test, signed ranked Wilcoxon's test and Student's t test were performed for repeated measures. For all analyses, $p < 0.05$ was considered a significant difference.

Results

The final sample comprised thirty professional Spanish lifeguards [23 males, 7 females; median age 22 years (IQR: 21–26); median weight 70 kg (IQR: 64–76); median height 172 cm (IQR: 170–178)]. All lifeguards successfully passed the 2-minute CPR pre-test, meeting the quality threshold required to participate in the experimental phase of this study (conducting scenarios S1 and S2).

Table 1 shows that during 10 min of CPR, the number of ventilations significant increases when ventilation continues during AED analysis (S2). The increase from 47 s (S1) to 72 s (S2) ventilations result in the delivery of 17.1 L of additional air in S2 ($p < 0.001$). There is no significant alteration in the variables related to the CC.

These findings correspond to a reduction of the non-ventilation period from 176 s (S1) to 48 s (S2). At the same time, the non-compression period remains the same: 78 s (S1) compared to 76 s (S2). Specific details for each cycle are provided in addendum 1. This includes the possibility of delivering between five and eight ventilations with an average volume of 584 to 660 ml during AED analysis, with an average ventilation-free period per cycle of 12 to 14 s.

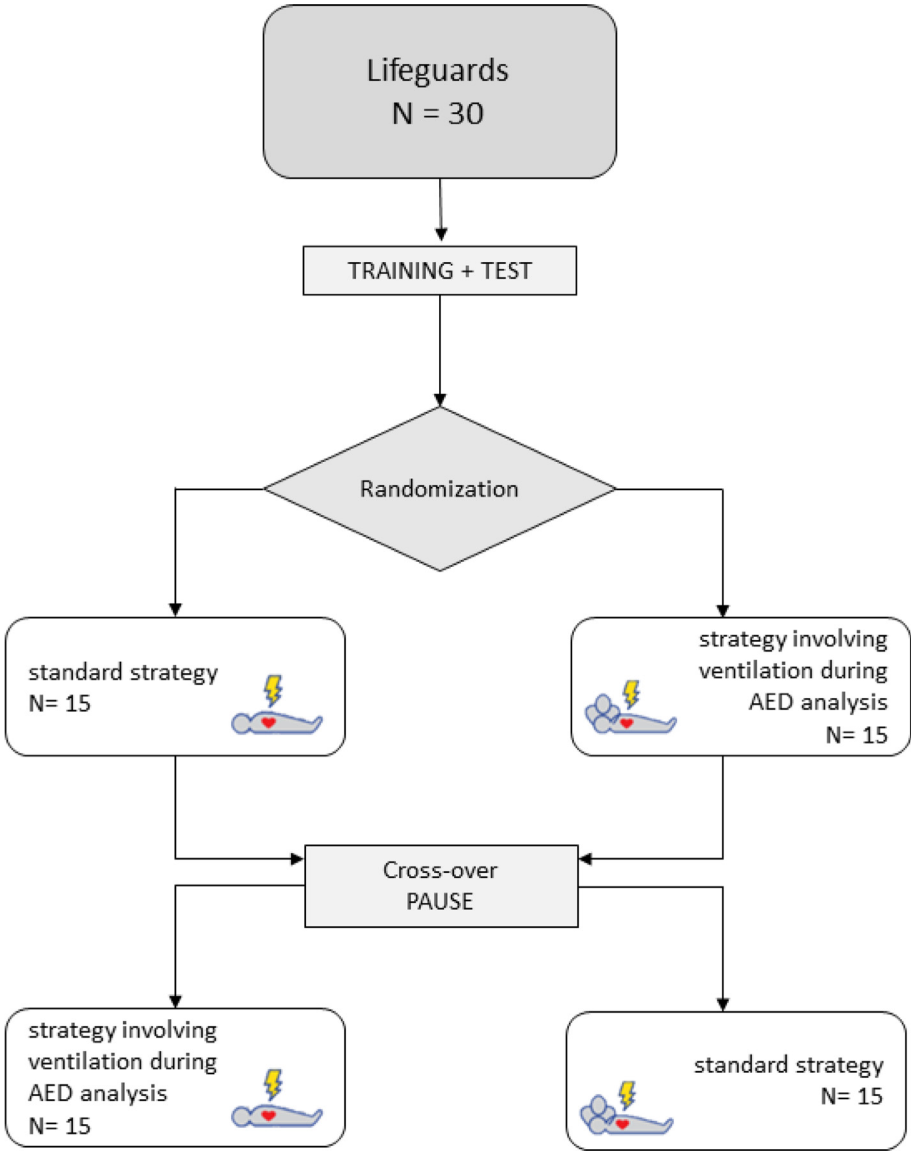


Fig. 1 – Flow chart of the cross-over design used to compare standard strategy (S1) with strategy involving ventilation during AED analysis (S2).

Table 2 shows the influence of *peri*-analysis pauses during AED analysis. The No-flow-time in ventilations significantly decreased in all pauses. In chest compressions, compression time increased only in the first and in the fourth pause for analysis.

Discussion

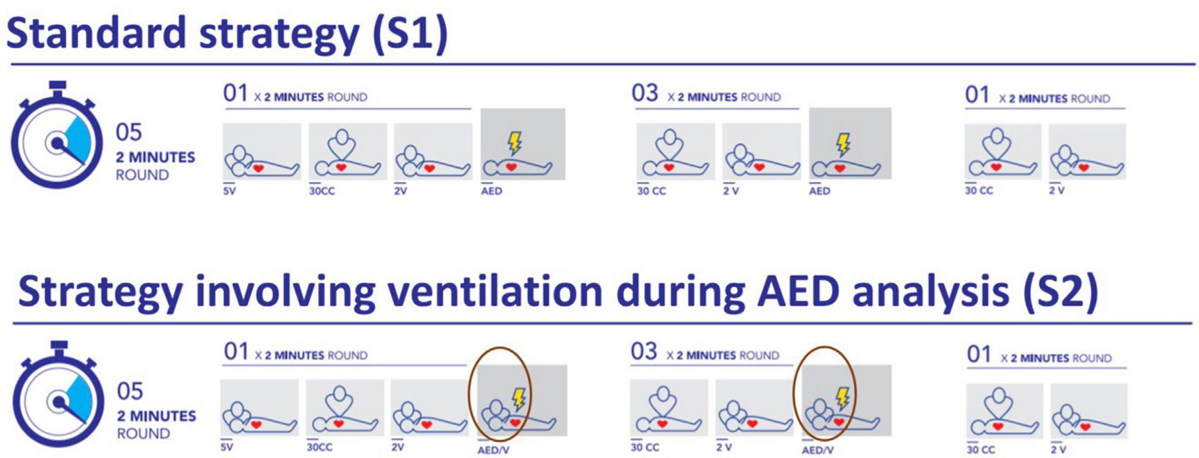
The study shows that this strategy significantly increases the number and total volume of ventilations without effects on the compressions. During 10 min of CPR a substantial extra amount of 17 L of air could be provided. At the same time, neither the number nor the time without compressions has changed.

At the moment of cardiac arrest following drowning, the body's oxygen levels have reached a fatally low point.[14] For this physiological reason, ventilation is likely to play a crucial role in the resuscitation of a drowned person. As suggested by ILCOR,[3] reversing hypoxia after drowning should be a priority, even before placing the AED. as it is a potentially reversible cause of cardiac impairment or cardiac arrest.[1,15,16]

This randomized cross-over simulation study most of all creates awareness that an alternative strategy for a drowning person may be considered that reduces the time between ventilation cycles. This, in addition to increasing the total volume of air without affecting the compression variables, could have an impact on increasing the likelihood of survival and favourable neurological outcome.[17]

Potential implications for practice

The most significant practical implication is the resuscitation of asphyxial cardiac arrest, such as in cases of drowning, especially in locations where EMS have a delayed response. Experimental and clinical data support the importance of early reversal of hypoxia as a critical intervention for improving outcomes. For this reason, The International Liaison Committee on Resuscitation (ILCOR) BLS/AED (Basic life support/automatic external defibrillator) Task Force recommends resuscitation with compressions and ventilations



V: ventilations; CC: chest compressions; AED: automated external defibrillator; AED/V: automated external defibrillator with ventilations.

Fig. 2 – Description of the two strategies: standard strategy (S1) follows the European Resuscitation Council guidelines 2015 of drowning and strategy involving ventilation during AED analysis (S2).

Table 1 – CPR variables during 10 min of CPR (N = 30).

Variables	Standard strategy		Strategy involving ventilation during AED analysis		p-value
	Median	IQR	Median	IQR	
Ventilation variables during 10 min of CPR					
Number of ventilations (#)	47	46–52	72	68–82	<0.001
Volume per ventilation (ml)*	634	550–787	641	529–809	0.77
Total volume administrated (L)*	32.4	26.4–38.7	49.5	35.2–63.3	<0.001
Time without ventilations (s)	176	164–186	48	36–62	<0.001
Chest compressions variables during 10 min of CPR					
Total number of chest compressions* (#)	737	701–778	730	678–769	0.16
Rate of chest compressions (CC/min)*	117	107–122	115	107–119	0.35
Time without compressions (s)	76	70–77	78	72–90	<0.001
Mean depth (mm) *	51	43–54	51	43–57	0.82
CC with correct hand-position (%)	100	100–100	100	100–100	0.27
CC with correct release (%)	81	49–98	83	64–96	0.55
CC with correct depth (%)	38	11–78	43	16–72	0.53
CC with correct rate (%)	82	30–97	88	62–97	0.11

CPR: cardiopulmonary resuscitation; IQR: Interquartile range (Q1-Q3); CC: chest compressions.
p-value: Signed ranked Wilcoxon for repeated measures ($p < 0.05$)/* Student's t test for repeated measures ($p < 0.05$).

Table 2 – Peri-analysis pauses during AED analysis (N = 30).

Variables	Standard strategy		Strategy involving ventilation during AED analysis		p-value
	Median	IQR	Median	IQR	
Ventilation Pauses					
Pause 1* (s)	45	38–49	12	5–16	<0.001
Pause 2* (s)	44	39–49	14	9–19	<0.001
Pause 3* (s)	46	38–50	12	6–16	<0.001
Pause 4 (s)	41	36–47	13	4–19	<0.001
Chest compressions Pauses					
Pause 1 (s)	18	17–22	20	18–23	0.043
Pause 2 (s)	18	17–19	19	17–22	0.22
Pause 3 (s)	18	17–19	18	17–22	0.30
Pause 4 (s)	18	17–19	19	17–22	0.008

AED: automatic external defibrillator; IQR: Interquartile range (Q1–Q3).
p-value: Signed ranked Wilcoxon for repeated measures ($p < 0.05$)/* Student's t test for repeated measures ($p < 0.05$).

whenever possible.[3] Additionally, providing effective ventilations is not always easy, as there are numerous factors that can influence poor quality (lack of experience, pre-fatigue after a rescue, or prolonged CPR).[17,18] Increasing the number of ventilations without affecting the other elements of BLS may compensate, maintain, or increase the success rate of ventilations delivered in prolonged basic life support.

Another important practical application could be the enhancement or development of AEDs to reliably detect the presence of circulation.[19] Resuscitation guidelines have removed the recommendation of pulse detection in the absence of breathing to initiate CPR.[20] This function could be extremely useful during a rescue (e.g. on an Inflatable Rescue Boat) when a drowning victim is in respiratory arrest but still has a pulse, focusing the rescuers' intervention on ventilations.

Limitations

Manikins studies may not reflect the real drowning situation on a beach or at a pool deck. Ventilation in drowned persons may also be more difficult due to acute pulmonary edema.[21] The standardised simulation setting, excluding confounders as much as possible, has however provided important quantitative data in what is the potency to reduce non-ventilation downtime in resuscitation following drowning.

The study was performed in 2019, just before the COVID-19 pandemic. At that particular time, ventilations were not recommended and it was decided not to further report on results of the study.[22] Since 2021, new recommendations have been published but none of them have affected the methodology of this study.[15,23]

This study has focused on asphyxial cardiac arrest, where the AED typically will not recommend delivering a shock. However, there are two confounding factors that must be considered in real-life scenarios. The first is that defibrillators prompt "don't touch the patient" during analysis, which may inhibit the actions of first responders from performing ventilations. The second is the effect of ventilations during analysis and their relationship with impedance as well as the Threshold of Ventricular Fibrillation (TTI), which increases during ventilation and decreases during expiration.[19,24]

Our research has followed current trends in the scientific literature on drowning,[1,3] establishing a protocol that increases the number of ventilations for the treatment of asphyxial cardiac arrest. However, there is still uncertainty regarding the effects of hyperventilation or increased ventilation rate follow drowning. Therefore, it is crucial that future studies focus on investigating this gap of knowledge.

Conclusions

This simulation study suggests that it is feasible to increase the number of ventilations during resuscitation following drowning, without affecting the quantity and quality of chest compressions. The results of this study may serve as a foundation for further investigation into optimal ventilation strategies in this context.

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CRediT authorship contribution statement

María Fernández-Méndez: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Roberto Barcala-Furelos:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Martín Otero-Agra:** Validation, Investigation, Formal analysis. **Joost Bierens:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100674.

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