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Assessment of over-the-head resuscitation method in an inflatable rescue boat sailing at full speed. A non-inferiority pilot study

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ABSTRACT

Introduction: Drowning is a public health problem. Interrupting the drowning process as soon as possible and starting cardiopulmonary resuscitation (CPR) can improve survival rates. Inflatable rescue boats (IRBs) are widely used worldwide to rescue drowning victims. Performing CPR in special circumstances requires adjusting the position based on the environment and space available. The aim of this study was to assess the quality of over-the-head resuscitation performed by rescuers aboard an IRB in comparison to standard CPR.
Methods: A quasi-experimental, quantitative, cross-sectional pilot study was conducted. Ten professional rescuers performed 1 min of simulated CPR on a QCPR Resuscy Anne manikin (Laerdal, Norway) sailing at 20 knots using two different techniques: 1) standard CPR (S-CPR) and 2) over-the-head CPR (OTH-CPR). Data were recorded through the APP QCPR Training (Laerdal, Norway).
Results: The quality of CPR was similar between S-CPR (61%) and OTH-CPR (66%), with no statistically significant differences ($p = 0.585$). Both the percentage of compressions and the percentage of correct ventilations did not show significant differences ($p > 0.05$) between the techniques.
Conclusion: The rescuers can perform CPR maneuvers with acceptable quality in the IRB. The OTH-CPR technique did not show inferiority compared to S-CPR, making it a viable alternative when boat space or rescue conditions do not allow the conventional technique to be performed.

1. Introduction

Drowning is a global public health problem, representing one of the leading causes of unintentional death worldwide [1]. The role of first responders ranges from drowning prevention to drowning mitigation [2]. When a drowning occurs, its severity will mainly depend on the time of submersion, as well as the speed of rescuers initiating resuscitation maneuvers [3]. Recently, there has been an increased scientific interest in the effects of immediate vs. delayed resuscitation in aquatic environments. However, the lack of research in this field leads to believe there is not yet sufficient evidence to indicate to aquatic rescuers the best recommendations for the initiation of early cardiopulmonary resuscitation (CPR) on a lifeboat. The latest review of the International Liaison Committee on Resuscitation (ILCOR) included CPR on rescue boats as a topic of analysis [4], given that it is a common equipment used by rescue agencies worldwide. The main advantages of this equipment are its safety, speed and manageability [5,6]. However, Inflatable Rescue Boats (IRB) also have several limitations, such as their small size and limited space for the crew. In this sense, this crew may consist of two operators: a skipper and a lifeguard, so in the event of a rescue that requires CPR, only one of the two crew members will be able to perform resuscitation maneuvers [6].

For all these reasons, the variety of out-of-hospital cardiac arrest situations, such as in the special circumstances of resuscitation, often require adaptations to the traditional CPR technique due to limited, variable and demanding spaces [7-9]. In some cases, alternative techniques such as the use of cardiocompressors in lifeboats have been proposed as an alternative to traditional CPR [10,11]. The Executive summary of European Resuscitation Guidelines 2021 (ERCG2021) [9] recommends starting resuscitation whenever cardiac arrest is recognized [12].

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Moreover, if there are trained first responders, these guidelines (in the special circumstances section) recommend starting CPR on the boat by performing compressions and ventilations [9]. These guidelines also indicate that the over-the-head CPR technique (OTH-CPR) is a potential option in limited spaces [9]. In fact, the OTH-CPR has demonstrated satisfactory results in simulation studies [13] and may be an alternative to mitigate the loss of CPR quality during high-speed navigation, especially during ventilations [4,14,15].

Thus, the aim of this study was, for the first time, to evaluate the feasibility and quality of CPR using the OTH-CPR versus the standard CPR technique (S-CPR) performed by a single rescuer while navigating in a rescue boat.

2. Method

2.1. Study design

A quasi-experimental randomized crossover design was used to analyze the differences between S-CPR and OTH-CPR techniques during a 1-min CPR test conducted while sailing at 20 knots in an IRB. The execution order of each technique was randomized, and to minimize the effect of fatigue, a 20-min rest period was given between them (Fig. 1).

2.2. Sample

A convenience sample of 10 professional lifeguards (4 women and 6 men) was voluntary recruited to participate in this study. The general characteristics of the participants were: age 21 ± 1 years, height 176 ± 5 cm, and weight 80 ± 15 kg. As inclusion criteria, the lifeguards had to be trained in CPR according to the recommendations of the European Resuscitation Council Guidelines for Resuscitation 2021 (ERCGR2021) [16] and they had to be re-accredited CPR training in the month prior to the study. They also needed to have knowledge of navigation techniques and experience working in IRBs. This research

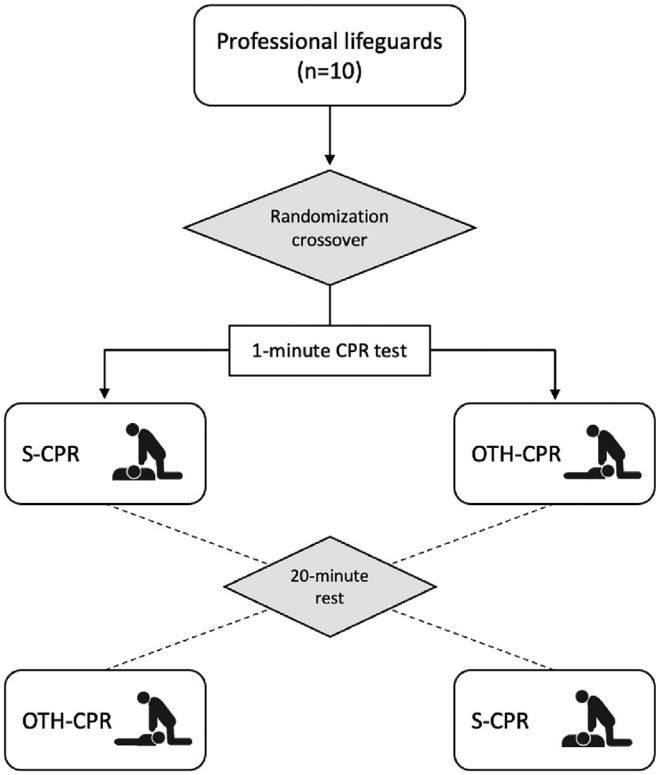

Fig. 1. Study design flowchart.

was approved by the Ethics Committee of the Faculty of Education and Sport Sciences (University of Vigo), with the code 09–280722, and developed in accordance with the Declaration of Helsinki. Prior to the study, the participants were informed about all the research procedures and signed a written informed consent.

2.3. CPR refresher

Before starting the test, in order to standardize skills, all participants received one one-hour sessions in which they were trained in compression and ventilation skills in the two CPR modalities: S-CPR and OTH-CPR. These training sessions were conducted by two professional instructors accredited by the Spanish Society of Intensive and Critical Medicine and Coronary Units and were in accordance with the recommendations of the ERCGR2021 [16], as well as following the OTH-CPR protocol described by Ćwiertnia et al. [13].

2.4. Variables and measuring procedures

CPR tests were performed on a Laerdal ResusciAnne manikin (Stavanger, Norway) and Ambu Mark IV adult BVM (Ballerup, Denmark) was used to administer the ventilations. During the tests, each rescuer had to perform CPR for 1 min following the recommendations for drowning (5 ventilations, followed by the 30, 2 sequence of CC, ventilations). Resuscitation variables were recorded using Laerdal Medical's QCPR Skill Reporter software (Stavanger, Norway) and according to the ERCGR2021 [16].

To assess the quality (%) of the chest compressions (QCC), the percentage of CC with a depth between 5 and 6 cm (CCD), the percentage of CC with adequate rate between 100 and 120 compressions per minute (RAT) and the percentage of CC with complete re-expansion of the chest (CCR) were considered. Therefore, the following formula was used: QCC = (CCD + RAT + CCR) /3. The quality of ventilations (QV) was calculated according to the percentage of effective ventilations in relation to the total number of attempted ventilations. In addition, the quality of CPR (QCPR) in percentage was calculated using the formula QCPR = (QCC + QV) /2.

2.5. Environment

Tests were conducted in April 2022 at Ladeira beach, located in Baiona (Pontevedra – Spain; latitude: 42.11267690189126, longitude: −8.834019576987323). During the test, the weather conditions were cloudy, with an air temperature 18–21 °C and calm wind (<5 knots). As for the sea conditions, there were slight waves, and the Douglas Sea Scale was 0–3 (<1.25 m).

2.6. Inflatable rescue boat

A semi-rigid rescue boat (IRB) was used (Valiant® model measuring 4 m in length and 1.5 m in width, equipped with a 40 hp. outboard Mercury engine), capable of sailing at a maximum speed of 30 knots on flat waters. The boat was crewed by two people, an operator and a lifeguard. Additionally, a member of the research team in charge of recording the test data also accompanied them. The manikin was placed in the middle of the boat without any restraint system (Fig. 2). The performance of both CPR techniques is also described in a video (Supplementary Material).

2.7. Statistical analyses

All analyses were conducted using the statistical package IBM SPSS for Windows (version 25.0. Armonk, NY: IBM Corp). Descriptive results for each variable are presented as mean ± standard deviation (SD), as well as median and the corresponding interquartile (IQ) range. Data normality was checked both graphically and using the Shapiro-Wilk

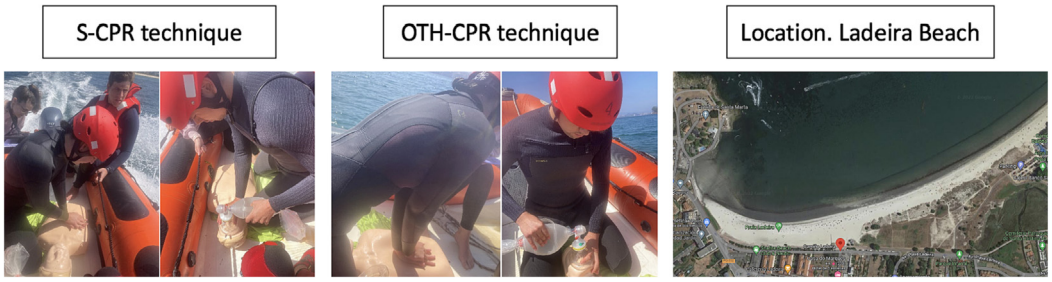

Fig. 2. Development of the tests and location of the study.

test. Student's *t*-test for related samples was performed to analyze the differences between the S-CPR and OTH-CPR techniques for parametric variables, while the Wilcoxon test for related samples was used for non-parametric variables. For all analyses, the significance value was set at $p < 0.05$.

3. Results

The differences in performance between the S-CPR and OTH-CPR techniques are shown in Table 1, while Fig. 3 depicts the individual changes in CPR performance between both techniques.

Focusing on the QCC, the performance of the rescuers was similar between the S-CPR and OTH-CPR techniques ($T = 0.010$; $p = 0.992$). No significant differences were found between techniques for the CCD ($Z = 1.129$; $p = 0.259$), RAT ($T = 0.945$; $p = 0.369$), and CCR ($Z = 0.524$; $p = 0.600$).

Regarding the QV, rescuers performed, on average, 21.4% better with the OVH-CPR technique than with the S-CPR technique, although this effect was not significant ($T = 1.449$; $p = 0.181$). Similarly, a non-significant increase (10.8%) in QCPR was observed with the OVH-CPR technique ($T = 1.473$; $p = 0.175$).

4. Discussion

The aim of this study was to assess the feasibility and quality of performing CPR (ventilation and compression maneuvers) from the head and compare the outcomes with those of conventional CPR. The main finding was that the OTH-CPR technique achieved acceptable quality values, similar to those of the S-CPR technique. Thus, it appears to be feasible and adequate for resuscitation in an IRB.

In recent years, several studies have analyzed CPR in rescue boats, both during simulations [5,17-21] and with real patients [22]. It is known that CPR in boats can vary depending on sea conditions [14,23] or speed [6]. However, to the best of our knowledge no previous research has compared the S-CPR technique with the OTH-CPR technique. The section on resuscitation in special circumstances in the ERCGR2015 [7] recommends the use of a lifeboat for increased safety of rescue teams, but there are no indications for on-board treatment. Moreover, the same section in the ERCGR2021 [9] indicates that the overhead position could be used in situations where space is limited.

A recent study conducted in Poland with 38 paramedics found better results for all CPR variables in a 5-min test using OTH-CPR [13]. Conversely, in the present study, no significant differences have been found in any variable, but the results also demonstrate a non-inferiority of OTH-CPR compared to S-CPR. Therefore, it seems reasonable to choose between the two techniques depending on the space available on the boat and its configuration, especially in rescue teams that use small boats such as IRBs.

4.1. Practical implications of the pilot study

Hypoxia is the most critical factor in the case of drowning [24], and in order to reverse cardiac arrest of asphyxia origin, ventilations are essential [4]. Previous studies have shown limitations in rescuers' ability to ventilate [4], regardless of whether mouth-to-mouth, pocket mask, or bag-valve mask resuscitation is used [5,19]. With the appearance of COVID-19, resuscitation protocols have recommended the use of bag-valve mask resuscitation as the first option for ventilation [25,26], and have pointed out the appropriate use by a rescuer is from the head. Bearing in mind that ventilations are the core element in drowning, rescuers must ensure the re-oxygenation of the victim. Lifeboat crew experience is a factor that could determine better performance during resuscitation [15], so the OTH-CPR technique should be integrated into lifeboat resuscitation training. From the point of view of safety on the boat and operability due to the lack of space, this technique appears to be a viable alternative in such situations.

4.2. Limitations of the study

This study has several limitations that should be noted. Firstly, this is a pilot study, and therefore an initial approximation to the technical execution in special conditions (small boat and a single rescuer). Studies with larger samples are necessary to evaluate the competence of the rescuers in the execution of the OTH-CPR and clearly determinate its feasibility. In addition, this study was carried out under optimal conditions, as both the IRB and the crew operated during the summer months

Table 1
Differences in performance between the S-CPR and OTH-CPR techniques.

	S-CPR			OTH-CPR			
	M ± SD	Median	IQ Range	M ± SD	Median	IQ Range	*p*-value
QCC	75.8 ± 9.0	75.7	66.9–82.4	75.8 ± 15.6	75.5	61.3–93.3	0.992[a]
CCD	95.2 ± 5.4	97.0	91.5–100.0	91.6 ± 8.7	93.0	91.8–95.5	0.259[b]
RAT	41.3 ± 22.6	41.0	26.8–56.5	48.8 ± 33.5	45.0	18.0–84.8	0.369[a]
CCR	90.8 ± 16.2	98.0	88.5–100.0	87.0 ± 27.9	96.5	89.0–100.0	0.600[b]
QV	45.7 ± 36.1	42.9	14.3–78.6	67.1 ± 30.2	71.4	39.3–100.0	0.181[a]
QCPR	60.7 ± 18.6	57.4	46.1–77.9	71.5 ± 15.4	69.0	59.7–87.3	0.175[a]

[a] Student *t*-test for related samples
[b] Wilcoxon test for related samples.

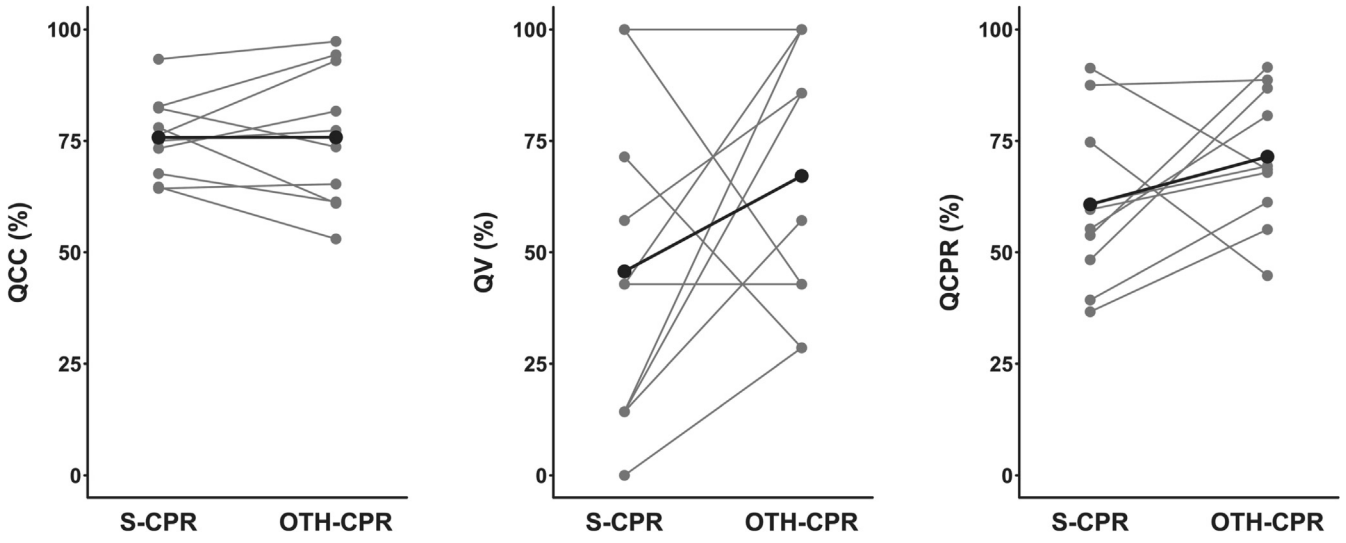

Fig. 3. Individual and mean changes in CPR performance between S-CPR and OTH-CPR techniques. S-CPR: Standard cardiopulmonary resuscitation. OTH-CPR: Over-the-head cardiopulmonary resuscitation. QCC: Quality of the chest compressions. QV: Quality of ventilations. QCPR: Quality of cardiopulmonary resuscitation.

in a beach environment. Other marine environments and weather conditions may lead to different results. Secondly, the results were obtained based on a simulation manikin, and the conditions of real victims are not the same, neither in anatomical characteristics nor in the results of the maneuvers. In real life, it can be more challenging to ventilate a drowning person, as resistance varies, and there is usually foam. Therefore, the results should take into account this important limitation. Thirdly, there is a multitude of small lifeboats with different configurations (center console, stern control, forward console, or sideways console), so the OTH-CPR technique may yield different results depending on whether it is performed forward, aft, or in different sea conditions. Fourthly, one more person was traveling in the boat than usual in the standard crew. This could affect the speed and stability of the IRB, although the low weight of the resuscitation manikin may compensate for this bias. More evidence should be obtained in the future on the performance of the OTH-CPR technique on larger vessels and in other less favorable sea conditions.

5. Conclusions

Lifeguards in this study were able to perform CPR with acceptable quality regardless of the technique used. There is no inferiority of the OTH-CPR technique compared to the S-CPR technique, indicating that OTH-CPR could be a viable alternative for resuscitations aboard small boats where space limitations restrict the rescuer's position.

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CRediT authorship contribution statement

Roberto Barcala-Furelos: Writing – review & editing, Writing – original draft, Resources, Investigation, Conceptualization. **Eloy Carracedo-Rodríguez:** Writing – review & editing, Writing – original draft, Resources, Data curation, Conceptualization. **Miguel Lorenzo-Martínez:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Alejandra Alonso-Calvete:** Writing – review & editing, Writing – original draft, Methodology, Data curation. **Martín Otero-Agra:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Cristina Jorge-Soto:** Writing – review & editing, Writing – original draft, Methodology, Data curation.

Declaration of Competing Interest

None.

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