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Short communication

Mouth-to-mouth ventilation is superior to mouth-to-pocket mask and bag-valve-mask ventilation during lifeguard CPR: A randomized study☆

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ABSTRACT

Aim: The quality of cardiopulmonary resuscitation (CPR) is a crucial determinant of outcome following cardiac arrest. Interruptions in chest compressions are detrimental. We aimed to compare the effect of mouth-to-mouth ventilation (MMV), mouth-to-pocket mask ventilation (MPV) and bag-valve-mask ventilation (BMV) on the quality of CPR.
Materials and methods: Surf lifeguards in active service were included in the study. Each surf lifeguard was randomized to perform three sessions of single-rescuer CPR using each of the three ventilation techniques (MMV, MPV and BMV) separated by 5 min of rest. Data were obtained from a resuscitation manikin and video recordings.
Results: A total of 60 surf lifeguards were included (67% male, 33% female, mean age 25 years). Interruptions in chest compressions were significantly reduced by MMV (8.9 ± 1.6 s) when compared to MPV (10.7 ± 3.0 s, $P < 0.001$) and BMV (12.5 ± 3.5 s, $P < 0.001$). Significantly more effective ventilations (visible chest rise) were delivered using MMV (91%) when compared to MPV (79%, $P < 0.001$) and BMV (59%, $P < 0.001$). The inspiratory time was longer during MMV (0.7 ± 0.2 s) and MPV (0.7 ± 0.2 s, $P < 0.001$ for both) compared to BMV (0.5 ± 0.2 s). Tidal volumes were significantly lower using BMV (0.4 ± 0.2 L) compared to MMV (0.6 ± 0.2 L, $P < 0.001$) and MPV (0.6 ± 0.3 L, $P < 0.001$), whereas no differences were observed when comparing MMV and MPV.
Conclusion: MMV reduces interruptions in chest compressions and produces a higher proportion of effective ventilations during lifeguard CPR. This suggests that CPR quality is improved using MMV compared to MPV and BMV.

1. Introduction

Administration of ventilations plays an important role in cardiopulmonary resuscitation (CPR), especially in asphyxial cardiac arrests.[1] The European Resuscitation Council recommends a ventilation duration of one second to achieve chest rise and effective ventilation. Likewise, reduction of interruptions in chest compressions (no-flow time) is crucial for maintaining coronary and cerebral perfusion.[2,3] Consequently, survival increases and neurological injuries following cardiac arrest can be reduced.[4–6] Previous studies have compared the ability of different ventilation techniques to deliver the recommended tidal volume[7] and inspiratory rates.[8] Except from over-ventilation resulting in gastric inflation and potential secondary lung injury, these variables are of unknown clinical importance.[9] No previous studies have compared the effect of ventilation techniques on no-flow time. Lay rescuers are recommended to use mouth-to-mouth ventilation (MMV),[2] while healthcare professionals provide bag-valve-mask ventilation (BMV) during CPR.[10] Mouth-to-pocket mask ventilation (MPV) is an effective alternative.[2] In the resuscitation of a drowning victim,

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Table 1
Characteristics of study participants ($n = 60$).

Mean age ± SD (years)	25.4 ± 5.9
Sex (*n*, %)	
Female	20 (33%)
Male	40 (67%)
Surf lifeguard certification year (mean ± SD)	2006 ± 4.4
Surf lifeguard experience (mean years ± SD)	4.4 ± 4.0
Preferred ventilation technique (*n*, %)	
Mouth-to-mouth ventilation	11 (18%)
Mouth-to-pocket-mask ventilation	42 (70%)
Bag-valve-mask ventilation	6 (10%)
No reply	1 (2%)
Healthcare professional (*n*, %)	
Yes	7 (12%)
No	53 (88%)
Educational level (*n*, %)	
None	1 (2%)
Primary and lower secondary school	2 (3%)
Gymnasium (equivalent to VI form college, preuniversity)	41 (68%)
Higher education (<2 years)	1 (2%)
Higher education (2–4.5 years)	7 (12%)
Higher education (>5 years)	8 (13%)

lifeguards are recommended to use MPV.[11] However, this recommendation is not evidence-based. The objective of this study was to compare the effect of MMV, MPV and BMV on CPR quality among surf lifeguards.

2. Methods

2.1. Participant recruitment and ethics

Eligible participants were professional, paid surf lifeguards in active service (seasonal: May–August) aged 18 or above. Participants were recruited from two Danish lifeguard organisations. All surf lifeguards complete annual mandatory CPR re-training before commencing active service. Demographic data on age, sex, certification year, surf lifeguard experience, occupation and preferred ventilation technique were collected (Table 1).

Study participation was voluntary and oral and written consent were obtained. In conformity with the Danish National Committee on Biomedical Research Ethics, no ethical review committee approval was required. The performance of individual lifeguards was only available to the investigators and was not disclosed to the lifeguard service leadership.

2.2. Design

Participants were randomized into six groups (Fig. 1) each performing three sessions of single-rescuer CPR on a manikin (Ambu™ Man, Ambu, Ballerup, Denmark), using three ventilation methods: MMV, MPV (Pocket Mask™, Laerdel, Stavanger, Norway) and BMV (the BAG II™ Disposable Resuscitator, Laerdal, Stavanger, Norway). Each session was of 3 min duration and separated by 5 min of rest. CPR was performed according to the European Resuscitation Council 2005 guidelines.[2] Standardised information about the test was given to participants without disclosing the hypothesis of the study. No instructions were given on how to perform CPR as participants complete mandatory annual pre-service training. Participants were allowed to kneel at both sides of the manikin, but they used the same side during all three sessions. Prior to each session, participants were allowed to familiarise themselves with the equipment. All sessions were conducted on the beach.

2.3. Data analysis

Throughout the study, the same manikin and mask system was used. The manikin was connected to a laptop, and data were recorded using Ambu® CPR Software (Ambu, Ballerup, Denmark). The equipment was calibrated before each session. The first four cycles of ventilations and compressions were examined and included in the data analysis. When participants stopped CPR to state that they would call the emergency medical services (EMS) or comparable statements, the cycle was excluded from analysis and substituted with the subsequent cycle. Custom-made software was employed to calculate the following variables: time to starting compression, compression rate and depth, no-flow time, tidal volume and inspiratory time. Each session was recorded on video and reviewed by two investigators assessing the proportion of effective breaths (visible chest rise). In case of disagreement, the video was reassessed and consensus was reached.

2.4. Statistics

All variables were tested for normality using D'Agostino-Pearson's test. The proportions of effective breaths were compared using McNemar's test. Continuous variables are reported as mean ± SD. Overall comparisons were made using analysis of variance (ANOVA) or Kruskal–Wallis test, and post hoc tests were performed when appropriate. $P < 0.05$ were considered statistically significant. Calculations were performed using GraphPad Prism (version 5.01; GraphPad Software, La Jolla, CA, USA) and QuickCalcs Online Calculators for Scientists (http://www.graphpad.com/quickcalcs/mcnemar1.cfm).

3. Results

A total of 63 surf lifeguards were invited to participate in the study of which two declined to participate. Of the 61 randomized individuals, one was excluded due to nightfall, as it was impossible to complete video recordings. Demographic information is shown in Table 1 (mean age: 25.4 years, male: 67% and female: 33%).

Results from single-rescuer scenarios are shown in Fig. 2. Overall, no-flow time significantly differed between the three groups (MMV: 8.9 ± 1.6 s, MPV: 10.7 ± 3.0 s and BMV: 12.5 ± 3.5 s) (Fig. 2A). MMV (91%) produced a significantly higher proportion of effective ventilations compared to MPV (79%, $P < 0.001$) and BMV (59%, $P < 0.001$). Inspiratory time was longer during MMV (0.7 ± 0.2 s) and MPV (0.7 ± 0.2 s) compared to BMV (0.5 ± 0.2 s) (Fig. 2B). During BMV, tidal volumes were significantly lower (0.4 ± 0.2 L) compared to MMV (0.6 ± 0.2 L) and MPV (0.6 ± 0.3 L), whereas no significant difference was observed when comparing MMV to MPV (Fig. 2C). No difference in time to starting compression was found (MMV: 21.1 ± 8.7 s, MPV: 23.1 ± 10.2 s and BMV: 23.7 ± 13.4 s) (Fig. 2D). A comparison of compression depth (MMV 32.1 ± 8.9 mm, MPV 31.7 ± 8.7 mm and BMV 31.5 ± 9.0 mm) and compression rate (MMV 112 ± 13 min^{-1}, MPV 110 ± 13 min^{-1}, BMV 112 ± 14 min^{-1}) revealed no significant differences between the three ventilation techniques (Fig. 2E + F).

4. Discussion

In this randomized study, we found that MMV significantly reduces interruptions in CPR and produces a higher proportion of effective ventilations compared to MPV and BMV. When MPV and BMV were used, there was a mean delay in starting compressions of 1.8 s and 3.6 s in each cycle compared to MMV (MMV 8.9 s, MPV 10.7 s and BMV 12.5 s). In Denmark, surf lifeguards often work on beaches far from EMS. Assuming 20 min of lifeguard CPR before

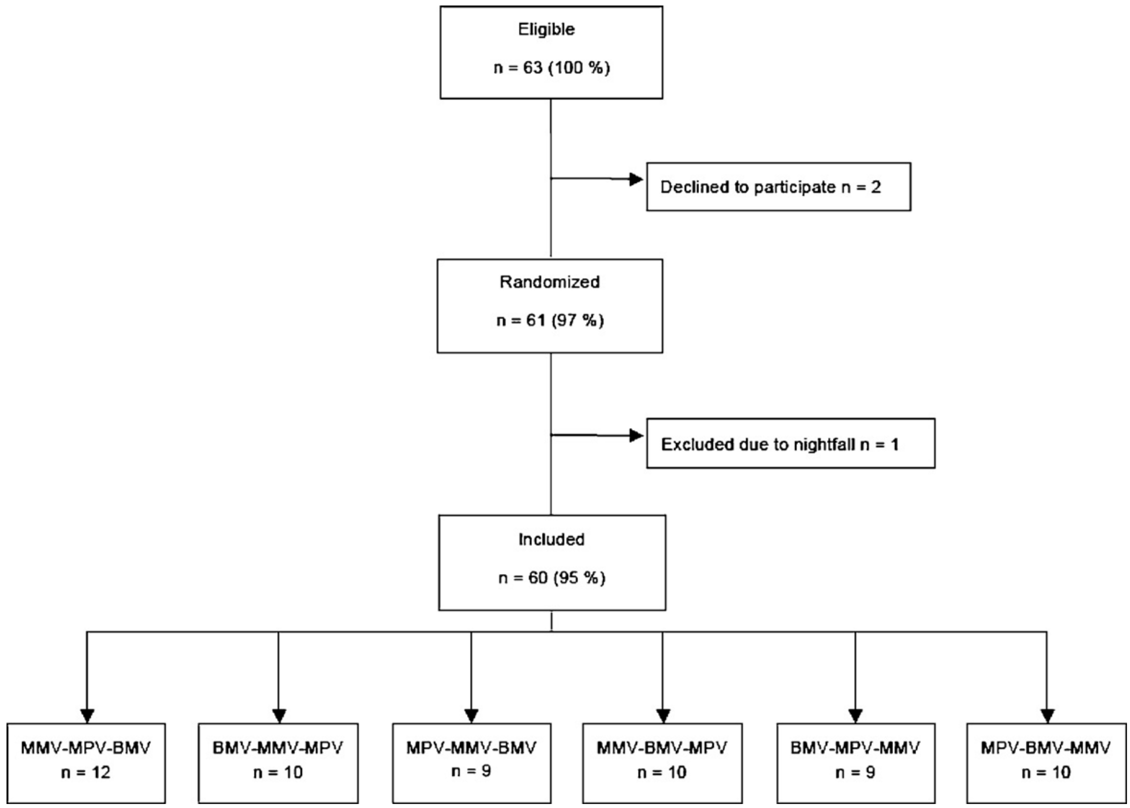

Fig. 1. Flow chart showing the inclusion of study participants ($n = 63$). MMV: mouth-to-mouth ventilation; MPV: mouth-to-pocket mask ventilation; BMV: bag-valve-mask ventilation.

arrival of the EMS at the beach and a compression–ventilation ratio of 30:2, the use of MMV reduces the total no-flow time by 50 s and 94 s compared to MPV and BMV. In the hands-off time during CPR, the coronary and brain perfusion fall precipitously, making prolonged interruptions in CPR detrimental.[4–6] Our study shows that using MMV instead of MPV and BMV can reduce the no-flow time. Furthermore, we have shown that the proportion of effective ventilations is higher when using MMV. Effective ventilation still remain an essential part of CPR[12], while it is even more important in asphyxial cardiac arrests such as drowning. Importantly, the above-mentioned differences were observed even though the majority of the surf lifeguards listed MPV as their first-choice technique (Table 1). Our study highlights the importance of training to further improve the use of MPV. Consistent with previous investigations we found that BMV also requires considerable skills and training.[2,13]

Our study showed that even among trained rescuers, compressions were generally too shallow. This finding is in accordance with previously reported data.[14,15] When training surf lifeguards, more emphasis should be put on this topic, as too shallow compression reduces survival.[16] Care must be taken that ventilations are not administered too forcefully or rapidly. In our study, the inspiratory time using the three ventilation techniques was too short (0.5–0.7 s) compared to guidelines, and it was significantly shorter using BMV. This might indicate that the potential risk of gastric inflation and lung injury is larger when using BMV.

Although 400,000 people are killed annually in drowning accidents worldwide,[17] no evidence-based recommendations on lifeguards' ventilation techniques are available. Before implementing any recommendation, several aspects should be considered. Importantly, in MMV no devices are needed, but on the other hand there is a minimal risk of disease transmission.[18,19] Among lay rescuers, MPV has been shown to deliver a more appropriate tidal volume,[7] but this has not been investigated among surf lifeguards previously. Among some surf lifeguards it is common sense that BMV is a superior ventilation technique, however this differs from our results. One may argue that BMV delivers the highest proportion of oxygen compared to MMV and BMV, but as demonstrated in our study, this is not the case, when ventilations are delivered inefficiently. Although needing further investigations, theoretically a comparable amount of oxygen can be delivered using effective MMV combined with high flow oxygen (e.g. a nasal catheter).[20]

4.1. Limitations

Although manikins are widely employed in simulation studies, manikins might not adequately reflect a real life situation. Manikins do not present with any awkward appearance such as vomiting, which is likely to reduce the willingness to ventilate. Danish surf lifeguards training might slightly differ from surf lifeguard training in other countries. We evaluated a single-rescuer scenario because the majority of lifeguards included in our study work as single rescuers and were trained accordingly. Further studies should evaluate the possible benefit of two-person CPR on ventilation techniques and CPR quality. The use of BMV is not a mandatory part of the Danish lifeguard training, and this should be considered when interpreting our results. Finally, our study evaluates important variables, but the effect on survival needs to be investigated.

Conclusion

This study is the first to demonstrate that MMV is superior to MPV and BMV during simulated single-rescuer CPR, as it reduces the no-flow time and results in more effective ventilations. Our results suggest that compared to MPV and BMV, CPR quality is improved using MMV.

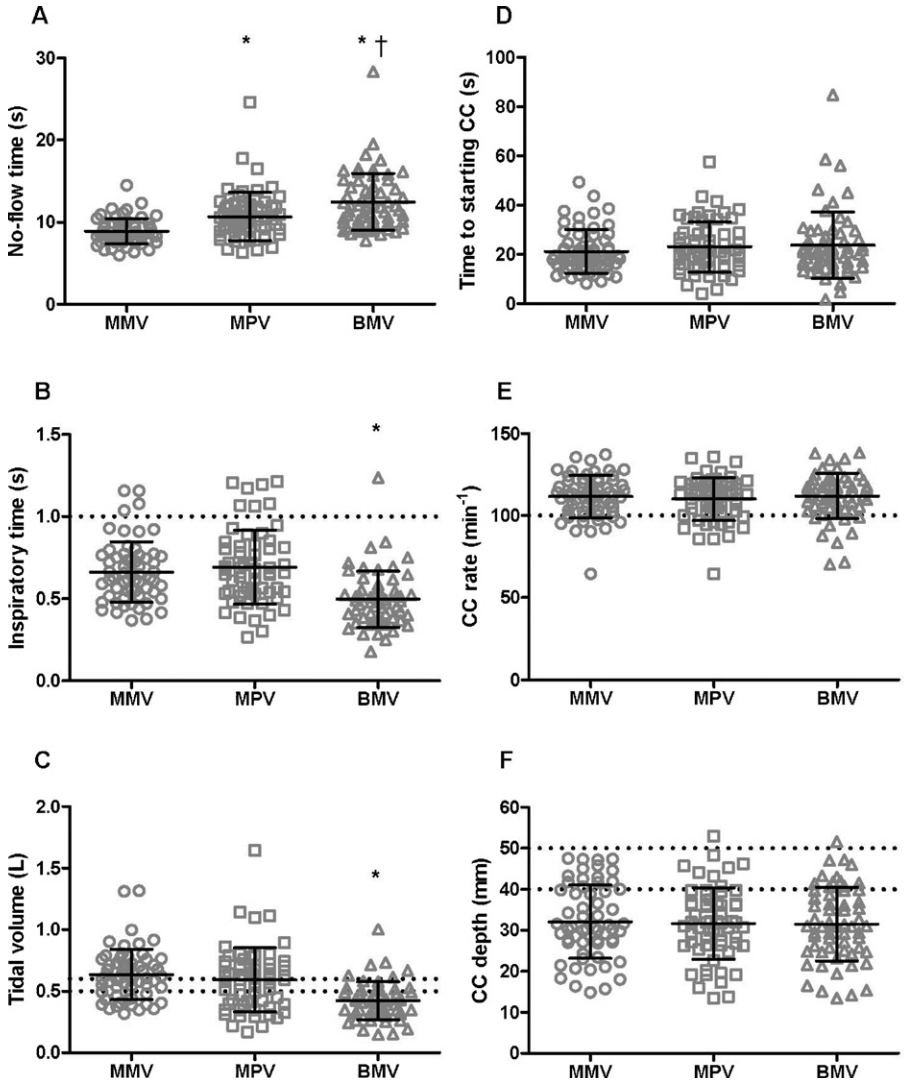

Fig. 2. (A) No-flow time reflecting interruptions in chest compressions due to ventilation. *$P < 0.001$ compared to MMV. †$P < 0.001$ compared to MPV. (B) Inspiratory time. Dotted line shows the recommended inspiratory time of 1 s. *$P < 0.001$ compared MMV and MPV respectively. (C) Tidal volume. Dotted lines show the recommended tidal volume of 0.5–0.6 L. *$P < 0.001$ compared MMV and MPV respectively. (D) Time to starting chest compressions. (E) Chest compression rate. Dotted line shows the recommended chest compression rate of 100 min^{-1}. (F) Chest compression depth. Dotted line shows the recommended chest compression depth of 40–50 mm. Data are mean ± SD. MMV: mouth-to-mouth ventilation; MPV: mouth-to-pocket mask ventilation; BMV: bag-valve-mask ventilation; CC: chest compressions.

Conflict of interest

None of the authors have conflicts of interest to declare.

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