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FEASIBILITY OF A MODIFIED STRATEGY FOR 2-RESCUER CARDIOPULMONARY RESUSCITATION

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☐ **Abstract—Background: Cardiopulmonary resuscitation (CPR) requires effective chest compressions and ventilations to circulate and oxygenate blood. It has been established that a 2-handed mask seal is superior when providing bag-valve-mask (BVM) ventilations. However a 1-handed technique remains the standard with which health care providers are trained to perform 2-rescuer CPR. Objectives: We sought to determine if a modified 2-rescuer CPR technique that incorporates a 2-handed mask seal during ventilations can be accomplished without compromising chest compression quality during a simulated cardiac arrest. Methods: Medical student volunteers were divided into an "intervention" arm, with 1 rescuer creating a 2-handed mask seal and the second rescuer performing chest compressions followed by that second rescuer squeezing the BVM bag to deliver ventilations during compression pauses, and a "control" arm, in which standard 2-rescuer CPR was performed. Both arms received a brief CPR refresher following a standard script. The 2 rescuer teams then performed 2 rounds of CPR on a manikin while being video recorded. Data were collected from real-time evaluation and post hoc video analysis. Results: Forty-seven pairs of students enrolled in the study. There were no statistically significant differences between the intervention and control arms for median (interquartile range [IQR]) compression fraction (72% [69.5–75.7%] vs. 73.2% [69.1–76.1%]; $p = 1.0$), median time to complete 2 rounds of CPR (207.8 s [198.5–222.9 s] vs. 214.7 s [201.3–219.5 s]; $p = 0.625$), median hands-off time (49.8 s [46.2–63.0 s] vs. 55.4 s [50.4–65.2 s]; $p = 0.278$), or median time for 30 compressions (15.2 s [14.3–15.9 s] vs. 15.4 s [14.6–16.3 s]; $p = 0.452$). Conclusion: Two-rescuer CPR incorporating a 2-handed face mask seal can be performed effectively without impacting chest compression quality during simulated cardiac arrest.**

☐ **Keywords—airway management; CPR; simulation**

Reprints are not available.

INTRODUCTION

The goal of cardiopulmonary resuscitation (CPR) during cardiac arrest is to deliver oxygen to the heart and central nervous system while restoring spontaneous circulation. This requires the delivery of chest compressions and ventilations. When health care providers perform CPR without an advanced airway, ventilations are performed with a 30:2 compression to ventilation (C:V) ratio using a bag-valve-mask (BVM) device to provide positive pressure. This technique has traditionally been taught with the "EC grip": one hand maintains the mask seal while the other hand squeezes the bag (Figure 1A). Maintaining airway patency in the unconscious patient typically

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combines 3 maneuvers: jaw thrust, chin lift, and head tilt. It can be technically challenging to perform all 3 maneuvers without compromising the mask seal while using only one hand. This skill is difficult to learn and maintain, especially for providers who do not perform mask ventilation routinely, and has been shown to be more difficult for providers with smaller hands to use effectively (1). As a result, inadequate ventilation may frequently occur (2,3).

An alternate technique, the thenar-eminence grip or "TE grip," uses the thenar eminence of both hands to maintain the mask seal while the fingers pull the mandible upward and tilt the chin, maintaining upper airway patency (Figure 1B). One provider maintains the seal while the second provider squeezes the bag to deliver ventilations. The TE grip has been shown to be superior to the EC grip for delivery of ventilations (1,2).

The primary outcome studied was to evaluate whether the rescuer providing chest compressions during 2-rescuer CPR could effectively deliver not only quality chest compressions, but also ventilations, by squeezing the BVM device during chest compression pauses, while the second rescuer maintained airway patency and a face-mask seal using the 2-handed TE grip (Figure 2). It is well-recognized that the TE grip is superior to the EC grip for the delivery of effective rescue ventilations. If this modification to 2-rescuer CPR can be performed without compromising chest compression quality, it has the potential to lead to better oxygenation and ventilation of patients in cardiac arrest. Secondary outcomes studied were differences in compression fraction (time spent actively delivering compressions divided by total time to complete the simulation), time to complete 2 rounds of CPR (1 round being 5 cycles of 30 compressions and 2 ventilations), hands-off time (total time not actively delivering chest compressions), and time to deliver 30 compressions.

METHODS

This prospective study was approved as exempt human research as defined by U.S. Department of Health and Human Services regulations (45 CFR 46. 101[b] [1 and 2]) by the Icahn School of Medicine at Mount Sinai Institutional Review Board. Informed consent was waived.

Participants were first- and second-year medical students from a single institution who had undergone American Heart Association (AHA) Basic Life Support (BLS) for Healthcare Providers CPR training once within the last 15 months. Those with previous clinical experience performing CPR or using the BVM device and those with advanced knowledge of CPR techniques (i.e., former nurses, emergency medical technicians, paramedics, CPR instructors, etc.) were excluded from participation in this

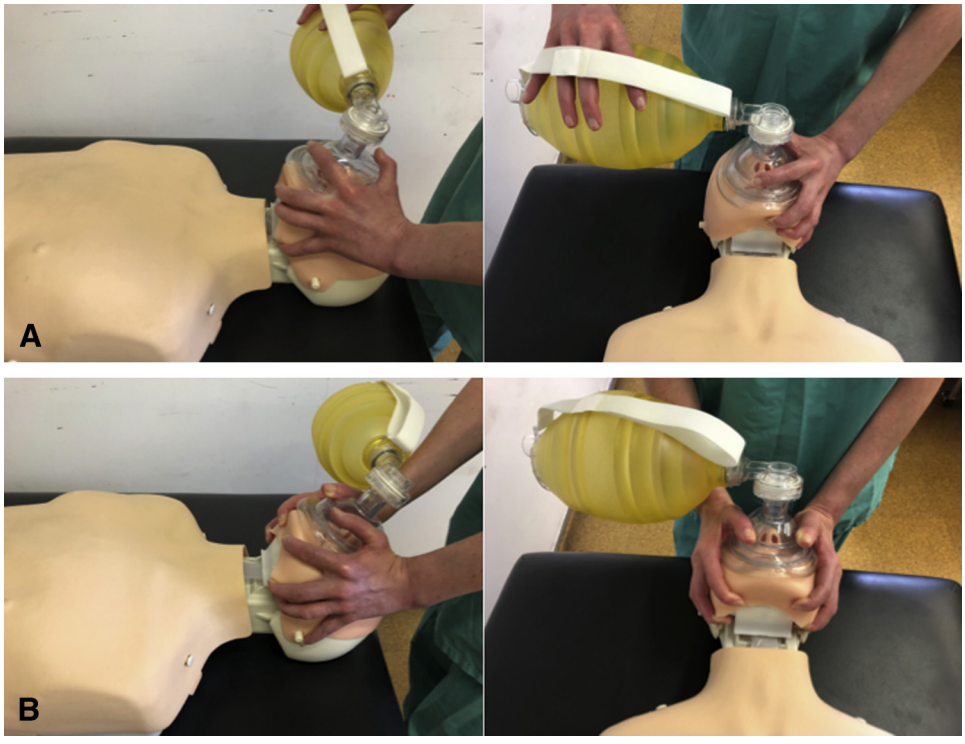

Figure 1. Mask seal techniques. (A) One-handed "EC" grip used in the control group. (B) Two-handed thenar eminence ("TE") grip used in the intervention group.

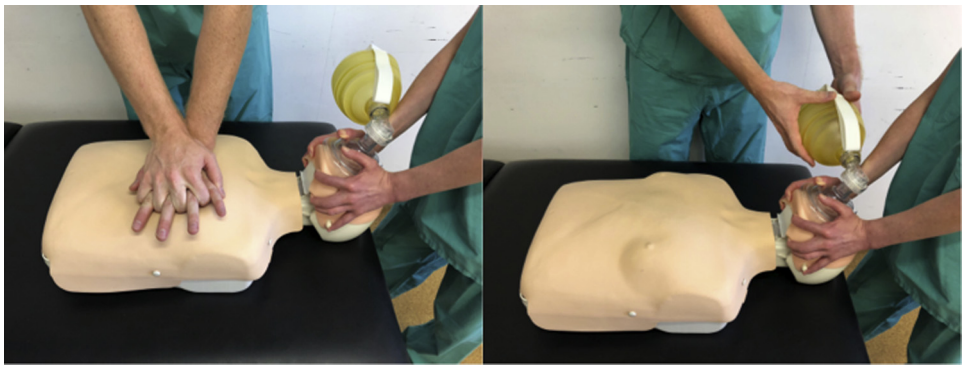

Figure 2. Rescuer roles with modified cardiopulmonary resuscitation (CPR) technique. During pauses in chest compressions in 2-rescuer CPR with a 30:2 compression to ventilation ratio, the rescuer performing chest compressions squeezes the bag, while the other rescuer maintains a mask seal with a 2-handed thenar eminence "TE" grip.

study to maintain homogeneity of skill level within the group. Participants were blinded to the purpose of the study, the primary hypothesis, and the primary and secondary outcome measures.

The study period consisted of five 1-h sessions each day from October 16, 2017 to October 20, 2017. Students volunteered to participate using an electronic form to prevent repeated participation. Those enrolled on days 1 and 3 were assigned to the control arm, those on days 2 and 4 were assigned to the intervention arm, and those enrolled on day 5 were split to attempt to enroll an equal number in each arm.

All participants were gathered in a holding room during their assigned session. They were then given brief instructions on how to perform CPR with the standard EC grip (i.e., the control method) or the 2-handed TE grip (i.e., the intervention method). The review was taught by the same 2 certified AHA BLS instructors each day, following a similar script in each arm. Participants were told they would be working with a partner to perform approximately 5 min of CPR on a manikin while being observed and recorded. The participants were instructed to switch roles after 5 cycles of CPR, as is consistent with AHA BLS guidelines (4).

After the instructional session, each participant was allowed to practice on a manikin in the holding room. After they felt comfortable and were able to demonstrate to the instructor their ability to successfully deliver ventilations, participants were instructed to organize themselves into pairs, and the pairs were sent to an evaluation room. Each evaluation room was equipped with a stepstool, an examination bed, a Resusci-Anne CPR manikin (Laerdal Corp., Fishkill, NY), a video recording device, and an evaluator. The evaluators were 3 anesthesiologists and 2 certified AHA BLS instructors. Participants were asked again if they had any questions about their responsibilities that the evaluator could answer. The recording device was then turned on and the evaluator read a script detailing the scenario after which the participants began CPR. The participants were observed and recorded as they delivered 2 rounds of 5 cycles of CPR, switching roles after the first round. After the second round of CPR, the evaluator informed the participants that the patient began to breathe spontaneously and concluded the simulation.

Evaluators were instructed to gauge apparent successful ventilations by the obtaining of a visible rise of the chest of the manikin and to note any deviations from the protocol. The tidal volume delivered was not directly measured. All studied metrics were evaluated via review of the video recordings made during the delivery of CPR obtained in the study room. Compression time was measured from the start of the downstroke of the first compression to the end of the upstroke of the last compression of a given cycle. Ventilation time was measured as the time from the end of the upstroke of the last compression of a given cycle to the start of the downstroke of the first compression of the next cycle. Time to switch roles was measured from the end of delivery of the final ventilation of the fifth cycle of the first round to the time the second rescuer placed their hands on the manikin's chest to commence the first cycle of the second round.

Other calculated metrics included the total time for 2 rounds (measured as the time from when the first rescuer put their hands on the manikin's chest to completion of last ventilation), compression fraction as defined earlier, and time spent without hands on the manikin (hands-off time). All times were measured by time-stamping the videos using multimedia software capable of measuring to the tenth of a second (Media Player Classic-Home Cinema, v 1.7.13, available at https://www.mpc-hc.org; iMovie v 10.0, Apple Inc., Cupertino, CA).

Statistical Analysis

All data were collected and managed with Microsoft Excel (Microsoft, Redmond, WA) with statistical

analyses performed using SAS software (v 9.4; SAS Institute, Cary, NC).

Baseline demographics between the 2 arms were compared using chi-squared tests. Wilcoxon rank sum tests were used to compare the distributions between arms for the primary and secondary outcomes.

A sensitivity analysis was performed to replace all data from 5 pairs (3 control pairs and 2 intervention pairs) that were excluded because of recording equipment malfunction or protocol deviation. We imputed missing data assuming a conservative scenario, favoring the control arm to ensure that our reported conclusions would not have been significantly impacted. For the control arm pairs with missing data, the 75th percentile value from the range of values seen in the control arm was used to impute percentage of successful ventilations and compression fraction, and the 25th percentile values were used to impute total hands-off time, time to complete 2 cycles, and time to deliver 30 compressions. For the intervention arm pairs with missing data, the 25th percentile value from the range of values in the intervention arm was used to impute percentage of successful ventilations and compression fraction, and the 75th percentile values were used to impute total hands-off time, time to complete 2 cycles, and time to deliver 30 compressions.

RESULTS

Ninety-four first- and second-year medical students participated in the study (22 control pairs and 25 intervention pairs). Four pairs (3 control pairs and 1 intervention pair) performed 1 extra cycle of CPR, and these extra cycles were excluded from analysis. Two pairs in the intervention arm had video recording malfunctions and were excluded from analysis. Three other pairs were excluded from primary analysis because of CPR protocol deviations: 1 pair (control arm) ended their second round after only 4 cycles, 1 pair (control arm) performed 5 cycles with 25 compressions in the first round, and 1 pair (control arm) performed 4 rounds of 3 cycles where the participants switched twice. All excluded pairs were included in the sensitivity analysis as described earlier. The primary analysis included 19 pairs in the control arm and 23 pairs in the intervention arm.

There was a significant difference in the distribution of the class year of participants across the study arms. Although the study was open to all first- and second-year students each day of the study period, most participants in the control arm were first-year students (71.1% vs. 30.4%, $p < 0.001$).

The median percentage of successful ventilations was 100% (interquartile range [IQR] 90–100%) in the 2-handed ventilation (intervention) arm and 80% (IQR 70–90%) in the 1-handed ventilation (control) arm ($p < 0.001$). The control arm did not differ significantly from the intervention arm in median compression fraction (72% [IQR 69.5–75.7%] vs. 73.2% [IQR 69.1–76.1%]; $p = 1.0$), median time to complete 2 rounds of CPR (207.8 s [IQR 198.5–222.9 s] vs. 214.7 s [IQR 201.3–219.5 s]; $p = 0.625$), median hands-off time (49.8 s [IQR 46.2–63 s] vs. 55.4 s [IQR 50.4–65.2 s]; $p = 0.278$), median time for 2 ventilations (4.7 s [IQR 4.2–5.9 s] vs. 5.2 s [IQR 4.6–6.1 s]; $p = 0.236$), or median time for 30 compressions (15.2 s [IQR 14.3–15.9 s] vs. 15.4 s [IQR 14.6–16.3 s]; $p = 0.452$) (Table 1).

The median percentage of successful ventilations in the intervention arm remained significantly higher than in the control arm (82.5% [IQR 70.83–87.86%] vs. 100.00% [92.5–100.0%]; $p < 0.001$) in the sensitivity analysis that included all pairs with missing values imputed. There continued to be no significant difference in time to deliver 2 cycles (203.9 s [IQR 198.55–219.4 s] vs. 214.8 s [IQR 203.1–218.8 s]; $p = 0.273$), median hands-off time (47.6 s [IQR 46.6–60.8 s] vs. 57.0 s [IQR 50.7–62.3 s]; $p = 0.091$), median time to deliver 30 compressions (15.35 s [IQR 14.5–15.75 s] vs. 15.2 s [IQR 14.7–16.1 s]; $p = 0.775$), and median compression fraction (74.01% [IQR 70.61–75.38%] vs. 72.69% [IQR 69.66–75.95%]; $p = 0.589$) (Table 2).

Table 1. Outcome Measurements for Cardiopulmonary Resuscitation with 1-Handed (Control) vs. 2-Handed (Intervention) Mask Seal Technique

	Control (n = 19)	Intervention (n = 23)	*p* Value*
Time for 2 rounds, seconds, median (IQR)	207.8 (198.5–222.9)	214.7 (201.3–219.5)	0.625
Compression fraction, %, median (IQR)	72.0 (69.5–75.7)	73.2 (69.1–76.1)	1.00
Hands-off time, seconds, median (IQR)	49.8 (46.2–63.0)	55.4 (50.4–65.2)	0.278
Percent successful ventilations, %, median (IQR)	80.0 (70.0–90.0)	100.0 (90.0–100.0)	<0.001
Time for 2 ventilations, seconds, median (IQR)	4.7 (4.2–5.9)	5.2 (4.6–6.1)	0.236
Time for 30 compressions, seconds, median (IQR)	15.2 (14.3–15.9)	15.4 (14.6–16.3)	0.452

IQR = interquartile range.
* Reported from Wilcoxon rank sum test.

Table 2. Sensitivity Analysis for Cardiopulmonary Resuscitation with 1-Handed (Control) vs. 2-Handed (Intervention) Mask Seal Technique After Imputing Missing Data

	Control (n = 22)	Intervention (n = 25)	*p* Value*
Median time for 2 cycles, seconds (IQR)	203.90 (198.55–219.40)	214.80 (203.10–218.80)	0.273
Median compression fraction, % (IQR)	74.01 (70.61–75.38)	72.69 (69.66–75.95)	0.589
Median hands-off time, seconds (IQR)	47.60 (46.60–60.80)	57.00 (50.70–62.30)	0.091
Percent successful ventilations (IQR)	82.50% (70.83–87.86)	100.00 (92.50–100.00)	<0.0001
Median time for 2 ventilations, seconds (IQR)	4.55 (4.20–5.80)	5.30 (4.60–5.85)	0.066
Median time for 30 compressions, seconds (IQR)	15.35 (14.50–15.75)	15.20 (14.70–16.10)	0.775

IQR = interquartile range.
Normalized subjects in the control group are a composite of the 75th percentile for successful ventilations and compression fraction and the 25th percentile for total hands-off time, time to complete 2 cycles, time to deliver 2 ventilations and time to deliver 30 compressions.
Normalized subjects in the intervention group are a composite of the 75th percentile for successful ventilations and compression fraction and the 25th percentile for total hands-off time, time to complete 2 cycles, time to deliver 2 ventilations and time to deliver 30 compressions.
* Reported from Wilcoxon rank sum test.

DISCUSSION

Our results show that an easily taught modification to 2-rescuer CPR with the chest compressor also squeezing the BVM device, freeing the other rescuer to create a 2-handed mask seal, delivers a higher proportion of effective ventilations, while not compromising chest compression quality during simulated 2-rescuer CPR compared with the conventional technique. We found no statistically significant differences between study arms for compression fraction, time to complete 2 rounds of CPR, hands-off time, time to deliver 2 ventilations, or time for 30 compressions. The median results in both arms were consistent with the 2015 AHA CPR guidelines for high-quality chest compressions: compression fraction >60%, no pauses in compressions >10 s, and a compression rate between 100 and 120 per minute (4).

Previous studies involving both manikins and patients have shown superior mask ventilation efficacy with a 2-handed technique (1,2,5,6). A study of anesthesia providers experienced in mask ventilation showed that 2-handed ventilation with oral airways resulted in less frequent inadequate ventilation (i.e., dead-space only or <150 mL) (2). Inadequate ventilation occurred in 8 of the 42 anesthetized patients during single-handed ventilation with oral airways and in 0 of the 42 patients during 2-handed ventilation. It is likely that during CPR performed by health care providers less experienced with mask ventilation (often without an oral airway), the proportion of inadequate ventilations may be higher.

There is also evidence that there may be poor adherence to the recommended C:V ratio of 30:2 with the currently taught technique of mask ventilation. In a simulation study examining errors in CPR by pediatric residents, only 9 of 70 participants performed synchronous compressions and ventilations (7). Asynchronous mask ventilation and chest compressions can decrease the effectiveness of both procedures because positive pressure ventilation will counteract ventricular filling, and chest compressions will decrease chest wall compliance and the efficacy of positive pressure ventilation via BVM. The method of 2-rescuer CPR evaluated in our study has the potential to increase adherence to the recommended 30:2 C:V ratio because the rescuer performing chest compressions must pause compressions in order to squeeze the bag for ventilations, though we did not assess adherence to technique in this study, and this question would require further investigation.

From a didactic perspective, the success of the intervention arm also shows that the modification in 2-rescuer CPR technique can be implemented rapidly and effectively. After a brief instruction and demonstration followed by supervised practice forming the mask seal, 46 medical students were able to use the technique in a simulated cardiac arrest scenario with a high degree of success. Further studies would be needed to evaluate the retention of the new technique.

The recent science regarding resuscitation underscores the importance of high-quality chest compressions as the key to improving survival after cardiac arrest (4). Therefore, any modification in CPR technique should not come at the expense of chest compression quality. The most recent International Liaison Committee on Resuscitation consensus statement recommends compression-only CPR in out-of-hospital cardiac arrests (OOHCAs) with bystander-initiated CPR because the complexity of delivering ventilations in this scenario could lead to unacceptable delays in initiating compressions, and the prospect of providing mouth-to-mouth ventilation may make some bystanders reluctant to intervene (8). However, for cardiac arrest managed by health care providers, a 30:2 C:V ratio with BVM ventilation is still recommended.

The odds of surviving cardiac arrest decrease dramatically as time increases between onset and defibrillation (9,10). As such, first responders and Emergency

Medical Services providers are a critical link in the "chain-of-survival" for OOHCA. Staffing in the in-hospital environment typically ensures that >2 providers will be available to assist with CPR in short order after a cardiac arrest. However, ambulances are often staffed with only 2 providers (11). The logistical challenges of prehospital resuscitation, which include moving the patient to the transport vehicle and transporting the patient to the hospital, can lead to extraneous interruptions in chest compressions (12). Despite the routine deployment of ALS providers to patients with OOHCA, studies continue to show questionable benefit to ALS intervention in the prehospital setting (13–15). This underscores the importance of maximizing the effectiveness of 2-rescuer BLS CPR in the prehospital setting.

Early tracheal intubation has been de-emphasized in the current guidelines, and there are mounting data questioning the utility of advanced airway management in the early phases of cardiac arrest (16,17). As evidence of this, 2 recent studies have shown that the use of currently available supraglottic airways are associated with outcomes comparable to, or even numerically superior to, intubation for patients with OOHCA (18,19). In addition, tracheal intubation within the first 15 min of in-hospital cardiac arrest has been associated with decreased survival to hospital discharge (20). This is potentially because of interruptions in chest compressions, delays in defibrillation or epinephrine administration, or postintubation hyperventilation with resultant decrease in cardiac output and reduction in cerebral blood flow. It is also possible that pauses in BVM ventilation during intubation attempts may lead to damaging hypoxemia.

Noninvasive mask ventilation therefore remains central in current CPR protocols, and efforts to improve its performance may improve overall CPR quality. The retention of mask ventilation skills after CPR training is poor (21). A retrospective study of 560 patients with OOHCA who received CPR with a 30:2 C:V ratio found that 75.7% of patients had lung inflation waveforms on the bioimpedance channel of defibrillator recordings during <50% of pauses in chest compressions, which suggests that fewer than half of attempted ventilations by BVM in those patients resulted in meaningful air movement. Measurable lung inflation in >50% of pauses was associated with an improved return of spontaneous circulation and survival to hospital discharge (3).

Limitations

There are limitations to our study. Students were chosen as study subjects both because of ease of recruitment and because this population allowed us to achieve a consistent level of inexperience among participants. Most health care providers do not work in fields where they will perform CPR or use a BVM device regularly in their careers, and therefore this study population allows some insight into the broader feasibility of this method. In a study of 224 physicians, paramedics, and medical students evaluating theoretical knowledge of CPR and CPR technical skills, no group's performance was superior, which supports our use of students as a prototypical health care provider (22). At our institution, all first-year students receive AHA BLS training and certification during their initial orientation. We enrolled both first- and second-year students, such that all participants had been certified in BLS either 3 or 15 months before the study period. Student volunteers were recruited between class times, and the relative availability of students from the 2 classes varied by day, leading to an imbalance between groups. Because of the differences in distribution of class year between the 2 arms, it is possible that difference in skill retention between first- and second-year participants may have influenced the results. Although the intervention group had a higher percentage of second-year students, both groups performed similarly in all aspects of the provision of CPR except for percentage of effective ventilations. In addition, the higher proportion of first-year students in the control arm, who were more recently certified in CPR and therefore more likely to perform CPR effectively, would bias the results toward the control arm.

The CPR manikin used allowed assessment of ventilations only via visible chest rise, rather than more nuanced assessments, such as tidal volume or presence of end-tidal carbon dioxide concentration. The investigators were not blinded to study arms, which could be a source of bias. It is also possible that the 2-handed mask ventilation technique leads to larger tidal volumes, which could paradoxically be detrimental to resuscitation efforts if large increases in intrathoracic pressure lead to detrimental hemodynamic effects (23,24). The potential negative effects of hyperventilation could not be assessed with this study design, but concerns regarding hyperventilation in the CPR literature have typically been with tracheal intubation and asynchronous ventilation (23–26).

Future studies could involve higher-fidelity manikins, some of the newest of which have the ability to measure tidal volumes, peak airway pressures, mean arterial pressures, and blood gas tensions to assess for more clinically relevant outcome differences between the 2 techniques. Retention of knowledge and technical skills could also be assessed by increasing the duration of time between instruction and evaluation of CPR technique.

CONCLUSIONS

The modified technique for 2-rescuer CPR described here has the potential to improve performance of ventilations

without any negative impact on chest compression quality. Additional studies are needed to determine if similar results can be achieved by other populations of health care providers.

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ARTICLE SUMMARY

1. Why is this topic important?

Despite evidence that a 2-handed mask seal provides superior bag-valve-mask ventilations, health care providers are still taught to use a 1-handed technique when working in 2 rescuer teams to perform cardiopulmonary resuscitation (CPR).

2. What does this study attempt to show?

A simple modification to the standard method of 2-rescuer CPR can incorporate a 2-handed mask seal without compromising the quality of chest compressions.

3. What are the key findings?

A modified 2-rescuer CPR technique using a 2-handed mask seal can be easily learned and implemented without compromising overall CPR quality.

4. How is patient care impacted?

These findings have the potential to improve the delivery ventilations to patients in the early phases of CPR and to improve cardiac arrest outcomes.