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ORIGINAL ARTICLE

Reassessing hyperventilation in prehospital care as a function of hand size

Maniraj Jeyaraju[1*], Ali Aledhaim[1], Thomas Grissom[1], Jon Mark Hirshon[1]

ABSTRACT

Background: Approximately 356,000 out-of-hospital cardiac arrests occur yearly (AHA, 2019), and prehospital providers must rely on their training to successfully resuscitate these patients. Despite advancements in their training, providers tend to hyperventilate patients, which has been linked to adverse health sequelae. While studies have briefly explored provider hand size as a variable, none have conclusively connected hand size and hyperventilation rates. Furthermore, minute ventilation (MV) has not been explored as a parameter of ventilation performance.

Methods: A focused revisit of this relationship between hand size and ventilation performance through manikin simulation testing of 122 emergency medical services professionals in Maryland evaluated the ventilator parameters of breath rate (BR), tidal volume (TV), and MV.

Results: The cohort's hyperventilation rate was 29%. In this study, evidence approaching statistical significance exists that participants with small hands (as determined by glove size) provide greater MV than other participants, yet no size-specific relationship was found for BR or TV. Further stratifying the participant certification level, the basic life support-certified providers with small hand sizes provided significantly greater BR administration.

Conclusion: These findings affirm that hyperventilation is still a concern, MV is an important ventilator parameter to include in future studies, and a larger scale study is needed.

Keywords: Ventilation, cardiac arrest, prehospital emergency care.

Introduction

In prehospital airway management, hyperventilation of patients continues to be an important problem. Hyperventilation is linked to numerous serious sequelae including gastric insufflation, compromised independent functional status in cardiac arrest patients, and negative neurological outcomes [1-4]. McInnes et al. [5] showed that healthcare providers in their study cohort (e.g., physicians, nurses, and a respiratory therapist) hyperventilated adolescent patients 63% of the time in an in-hospital setting. Vissers et al.'s [6] cohort hyperventilated (defined by Vissers et al. [6] as breath rate (BR) > 10/minute) their patients 85% of the time. The retraining of providers seems to be a logical solution to mitigating hyperventilation; however, studies noted questionable improvement [7,8]. The goal of this study was to assess if the tendency to hyperventilate is a by-product of operator characteristics, like hand size.

Hand size is one immutable operator characteristic that is variable across provider populations, and its effect seems intuitive: those with larger hands would apply greater force on the manually compressible bag valve mask (BVM) (e.g., Ambu bag), resulting in a greater tendency to hyperventilate. However, the relationship is not that simple, as evidenced by a few studies. Thomas et al. [9] studied the variance in tidal volume (TV) in BVM ventilation and reported a significantly lower TV in basic life support (BLS) trainees with small hands (445 ml) compared with the average (520 ml) and those with large hands (595 ml). Otten et al. [10] noted that female healthcare providers, who in their cohort had smaller hand width and initial dominant hand grip strength, had a "lower median expired tidal volume percentage." On the contrary, Khoury et al. [11] found that hand size did not

Correspondence to: Maniraj Jeyaraju
*Department of Emergency Medicine, University of Maryland School of Medicine, Baltimore, USA.
Email: maniraj.jeyaraju@som.umaryland.edu
Full list of author information is available at the end of the article.
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affect ventilation performance, while grip strength and professional status (e.g., physician and nurse providers) did. Similarly, Augustine et al. [12] also concluded the lack of a significant relationship between operator hand size and ventilation volumes. The lack of definitive results highlights a need for a focused revisit of hand size as an operator characteristic affecting ventilator performance.

Hand size has only been critiqued in terms of TV; yet, the multiplication of TV and BR - minute ventilation (MV) - may paint a much clearer picture. MV is inarguably important, because low TV and high BR performances may be equally damaging to the patient. Further studies could pave the way for alternative solutions for delivering appropriate MV, like using pediatric BVMs. This study sought to analyze the association between hand size, as determined by self-reported small versus non-small glove size, and MV delivered in a simulated respiratory arrest scenario using manikins.

Materials and Methods

Participants

One hundred twenty-two participants were recruited for this study between June 2018 and September 2019. The study was powered based on TV values from a prior study to achieve 90% power and set at a significance level of 0.05; the calculation yielded a minimum of 17 measurements per group (small *vs.* non-small glove size). All participants were Maryland-based emergency medical services (EMS) providers above 18 years of age certified in BLS or advanced life support (ALS). The study recruited a convenience sample (e.g., word-of-mouth and email advertisements) of providers, who were briefed about the study procedure and their rights as a study volunteer before participating. The study received exempt status approval from University of Maryland, Baltimore Institutional Review Board.

Respiratory arrest simulation

Each participant rotated through three stations, at each of which they were asked to ventilate an airway management manikin (RespiTrainer Advance; Ingmar Medical, Pittsburgh, PL) for 3 minutes. At each station, a RespiTrainer manikin was already connected to a different ventilation apparatus: BVM, endotracheal tube, or high seal bag-valve device (HSBVD). A HSBVD is an investigational device in which a continuous positive airway pressure face mask is attached to a BVM. The participants' only responsibility was to manually ventilate the manikin as they would for any respiratory arrest patient and, if applicable, maintain the seal with their other hand. Participants were given 3 minutes rest between stations.

Data collection and analysis

For each participant, RespiTrainer's software records a summary table for a preset interval of bagging detailing the following parameters:

- BR, TV, and peak pressure for each breath;
- Average BR, TV, peak pressure, and MV.

After completing the three stations, participants filled out a survey and were compensated 20 dollars in cash for their time and effort. Each participant's survey responses and ventilation performance data were linked through a unique study identifier. On the survey, those participants identifying as having small or extra-small glove size were classified as small glove size, while those identifying as having medium, large, or extra-large glove size were classified as non-small glove size.

The primary outcome was MV, defined as TV multiplied by BR. In this non-normal distribution, differences in MV by provider glove size were compared (small *vs.* non-small) using a chi-square test and Mood's median test. For chi-square test, hyperventilation was defined as MV > 7,200 ml/minute, obtained by multiplying American Heart Association guidelines recommending upper limits of 12 breaths/minute and 600 ml TV [13]. An effect modifier of interest was provider certification (ALS *vs.* BLS). Data were de-identified prior to analysis to mitigate bias. If there was missing data for a bagging event, it was excluded from analysis.

All statistical tests were two-tailed and the study considered a p-value less than 0.05 statistically significant. Statistical tests and Figure 1 were generated using Microsoft Excel for Office 365 MSO 16.0 (Microsoft Corporation, Redmond, WA) and Spyder (Scientific Python Development Environment) v.3.3.3 (Licensed to MIT, Cambridge, MA).

Results

Demographic and operator characteristic data were collected through the informational survey; the RespiTrainer software provided the ventilation performance statistics. Three providers did not provide crucial survey information and 22 providers used a manometer during ventilation; their information was excluded from analysis. Thus, the study analyzed a total of 97 participants and 291 ventilation performances. Ten participants classified themselves as small glove size, while the rest were non-small glove size. Participant characteristics are presented in Table 1. Most participants were male (57%), had BLS certification (72%), worked for a fire department-based EMS (92%), and served suburban areas (51%).

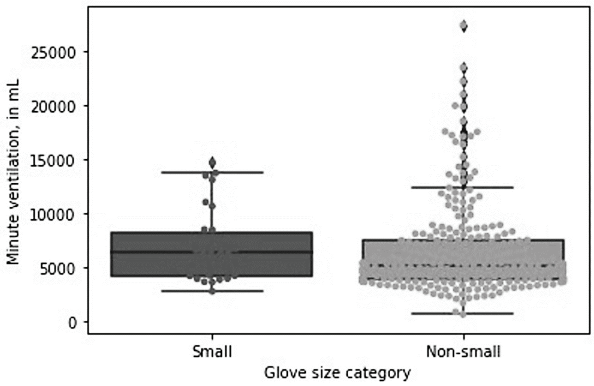

Figure 1. *MV distribution by provider's glove size.*

Table 1. Demographics of 97 study participants.

Characteristic	*n* (%)
Gender	
Male	55 (57)
Female	33 (34)
No response	9 (9)
Provider certification	
BLS	70 (72)
ALS	27 (28)
Provider area of service	
Rural	19 (20)
Suburban	49 (51)
Urban/city	27 (28)
Multiple areas	1 (1)
No response	1 (1)
EMS system served	
Fire department-based	89 (92)
Hospital-based	2 (2)
Commercial/private ambulance	2 (2)
Other	4 (4)

Table 2 and Figure 1 briefly summarize the findings pertinent to the primary outcome of the study, MV. The median MV for all performances was 5,324.8 ml/minute. The median (q_1, q_3) MV was 6,483 (4,256.7, 8,269.1) ml/minute and 5,234 (3,959.6, 7,520.0) ml/minute for the small and non-small glove size groups, respectively. The difference was not statistically significant (p = 0.051). The median TV and BR for all ventilation performances were 440 ml and 12.5 breaths/minute, respectively. Grouping the providers into those with small versus non-small glove sizes shows a lower TV but higher BR in the small glove size group compared to non-small glove size group. 25% of participant TV delivered was greater than 506.5 and 526.0 ml for small and non-small glove size groups, respectively. 25% of participant BR delivered was greater than 20.5 and 16.7 breaths/minute for small and non-small glove size groups, respectively.

Further subcategorizing participants by provider certification and using Mood's median test, the data set revealed a statistically significant difference between BLS-certified small and non-small glove size participants in the BR ventilation parameter only (p = 0.048). However, this difference was not present between the two ALS-certified glove size groups (p = 0.975). This analysis is presented in Table 3. The difference in MV between the small and non-small glove size groups disappeared when data was subcategorized by level of certification. Another area of interest to us is quantifying the rate of hyperventilation. Hyperventilation was observed in 84 of 291 (29%) ventilation performances, using the 7,200 ml/minute cutoff.

Discussion

Ventilation performances of a cohort of EMS professionals based in several Maryland counties were studied. The primary focus was to examine the association between MV and self-reported hand size. Although results did not reach statistical significance, there was a strong trend toward small glove size providers providing greater MV than those with non-small glove sizes. This trend was largely driven through an increase in delivered BR by small-glove size providers. The excessive BR administration associated with smaller hand size is consistent with prior studies [6,14]. Of knowledge, this is the first study characterizing the relationship between hand size and ventilation performance using MV as an outcome.

Previous studies, however, have examined this relationship using TV as an outcome. Otten et al. [10] found that women, who in their study cohort also had smaller hand sizes, provided lower TV than men, who had larger hand sizes. Augustine et al. [12] found a positive but weak correlation between hand size and TV. This study concurs with Khoury et al.'s [11] study finding that hand size did not significantly influence ventilation performance (p = 0.31). Both studies differ from the only study identified that concluded that hand size significantly impacts ventilation performance, specifically when using an endotracheal tube [15].

Further stratification of this data set by certification (ALS or BLS) yielded interesting results concerning BR, although not TV and MV. Regarding the primary outcome, ALS- and BLS-certified providers did not significantly differ in MV delivery. Mood's median test for MV yielded 6,547 ml/minute versus 5,429 ml/minute in the BLS-certified small versus non-small groups (p = 0.083) and 6,408 ml/minute versus 4,653 ml/minute in the ALS-certified small versus non-small groups (p = 0.414). Future studies should consider exploring MV as an outcome since MV captures both TV and BR. No significant difference was found in TV medians by provider certification. Similarly, three prior studies could not find differences in TV by professional status [11,12,16]. On the contrary, BR varied between glove size groups in the BLS cohort; in particular, participants with small glove size provided a significantly greater BR than those with non-small glove size (median 15 *vs.* 13; p = 0.048). The difference in BR was negligible in ALS-certified small and non-small glove size groups, with both delivering a median 11 breaths/minute. This difference between ALS- and BLS-certified providers may be due to inexperience in the BLS cohort, leading to greater variability in performance suggested by a wider interquartile range in the BLS-certified group's BR delivery.

Finally, the hyperventilation rate of 29% (84/291) was noted. This largely concurs with prior studies that found hyperventilation rates as high as 85% [5,6,8,11,17]. Consistent with results from this study, other studies noted that hyperventilation was due to high BR rather than TV [5,8,17]. One study tried replacing the adult BVM bag with a pediatric one and found that the mean TV significantly decreased, while oxygen saturation did not suffer [18].

Table 2. Median (q_1, q_3) ventilation performance by glove size.

Parameter	Small glove size	Non-small glove size	*p* value
TV, ml	432 (368.8, 506.5)	441 (361.0, 526.0)	0.715
BR per minute	15 (11.3, 20.5)	12 (9.8, 16.7)	0.224
MV, ml/minute	6,483 (4,256.7, 8,269.1)	5,234 (3,959.6, 7,520.0)	0.051

Table 3. Ventilation performance by glove size category and provider certification.

Provider certification	Ventilation parameter	Glove size category	Median (q_1, q_3)	*p* value
BLS	TV, ml	Small	415 (363.5, 454.3)	0.359
		Non-small	434 (356.0, 523.3)	
	BR per minute	Small	15 (11.9, 21.8)	0.048
		Non-small	13 (10.2, 20.0)	
	MV, ml/minute	Small	6,547 (4,239.4, 9,043.7)	0.083
		Non-small	5,429 (4,023.3, 8,215.7)	
ALS	TV, ml	Small	591 (518.8, 677.5)	0.096
		Non-small	450 (381.0, 532.0)	
	BR per minute	Small	11 (9.5, 13.2)	0.975
		Non-small	11 (8.1, 11.5)	
	MV, ml/minute	Small	6,408 (4,800.9, 7,102.9)	0.414
		Non-small	4,653 (3,732.9, 6,330.0)	

Conclusion

Although not statistically significant, this study found a trend toward statistical significance in MV delivery by glove size group during simulated resuscitation; paradoxically, the participants with small glove size delivered higher MV than those with non-small glove size, largely due to an increase in the delivered BR. In this cohort, this may be due to the tendency of providers with small glove size to ventilate at a higher rate than those with non-small glove size, possibly due to overcompensation on the part of the providers with small glove size. Additionally, the results largely concur with prior studies suggesting that hand size has no effect on TV. Stratifying by provider experience (ALS *vs.* BLS), BLS providers with a small glove size ventilated at a higher rate than those with non-small glove sizes. Given that this study is the first assessment of MV as a function of hand size, the results suggest a reassessment of this problem - prehospital provider-induced hyperventilation - using MV in larger scale studies. The primary limitation of this study is the generalizability of study results. Generalizability is hindered by the relatively small sample size, focus on one EMS system, and convenience sampling method. This study can be a stepping stone for more robust studies in the future.

List of Abbreviations

BR Breath rate
TV Tidal volume
MV Minute ventilation
BLS Basic life support
ALS Advanced life support
AHA American Heart Association

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article. Ali Aledhaim, DrPH NRP, is a reviewer for the Saudi Journal of Emergency Medicine.

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Consent to participate

Informed consent was obtained from all individual participants included in the study.

Ethical approval

The study received exempt status approval from the University of Maryland, Baltimore Institutional Review Board, dated 3/8/2018.

Author details

Maniraj Jeyaraju[1], Ali Aledhaim[1], Thomas Grissom[1], Jon Mark Hirshon[1]

1. Department of Emergency Medicine, University of Maryland School of Medicine, Baltimore, USA

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