Original Article

A survey of ventilation strategies during cardiopulmonary resuscitation

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BACKGROUND: Many controversies still exist regarding ventilator parameters during cardiopulmonary resuscitation (CPR). This study aimed to investigate the CPR ventilation strategies currently being used among physicians in Chinese tertiary hospitals.

METHODS: A survey was conducted among the cardiac arrest team physicians of 500 tertiary hospitals in China in August, 2018. Surveyed data included physician and hospital information, and preferred ventilation strategy during CPR.

RESULTS: A total of 438 (88%) hospitals completed the survey, including hospitals from all 31 Chinese mainland provinces. About 41.1% of respondents chose delayed or no ventilation during CPR, with delayed ventilations all starting within 12 minutes. Of all the respondents who provided ventilation, 83.0% chose to strictly follow the 30:2 strategy, while 17.0% chose ventilations concurrently with uninterrupted compressions. Only 38.3% respondents chose to intubate after initiating CPR, while 61.7% chose to intubate immediately when resuscitation began. During bag-valve-mask ventilation, only 51.4% of respondents delivered a frequency of 10 breaths per minute. In terms of ventilator settings, the majority of respondents chose volume control (VC) mode (75.2%), tidal volume of 6–7 mL/kg (72.1%), PEEP of 0–5 cmH_2O (69.9%), and an FiO_2 of 100% (66.9%). However, 62.0% of respondents had mistriggers after setting the ventilator, and 51.8% had high pressure alarms.

CONCLUSION: There is a great amount of variability in CPR ventilation strategies among cardiac arrest team physicians in Chinese tertiary hospitals. Guidelines are needed with specific recommendations on ventilation during CPR.

KEY WORDS: Cardiopulmonary resuscitation; Ventilation strategy; Questionnaire survey; Cardiac arrest team

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INTRODUCTION

The aim of cardiopulmonary resuscitation (CPR) is to give the cardiac arrest patient the best chance of achieving a return of spontaneous circulation and survival. At present, the American Heart Association (AHA) and European Cardiopulmonary Resuscitation Council (ECR) update their guidelines on CPR every five years. CPR, as the main treatment for sudden cardiac arrest, includes circulation, airway, breathing, and defibrillation, each of which is important for overall success. However, there are many controversies about when to establish an advanced airway, which ventilation method to choose and how best to set ventilator parameters. There are no detailed recommendations for ventilation strategies, and we have discovered the situation among tertiary hospitals in China is quite varied. Therefore, we conducted this questionnaire-based survey in order to assess the current state of ventilation strategies during CPR among cardiac arrest team physicians in China.

METHODS

Study design and population

The study utilized a cross-sectional survey design. We e-mailed links to a web-based survey to the cardiac arrest team directors of 500 tertiary hospitals in China in August, 2018. The hospitals were randomly selected from the 6,214 hospitals registered by the Chinese Medical Association using a computerized random number generator. Hospital characteristics were abstracted from the system, including total inpatient bed capacity, teaching hospital status, and location. We requested that the survey be completed by one of the physicians on duty responsible for cardiac arrest "codes" the day the e-mail was received. They were required to provide their personal information as well as their specialty, seniority, rank, and what kind of CPR training they had received (AHA, ECR, or Chinese domestic variety).

Survey contents

This survey was developed in accordance with the guidelines for the design and conduct of self-administered surveys of clinicians. After completing a literature review, a local panel of experts assisted in item generation, editing, and pre-testing. The complete electronic survey was then piloted at ten hospitals to ensure ease of use, precision, and comprehensibility. The survey used a fill-in-the-blank format and queried whether, during CPR, to start ventilation immediately, whether to strictly follow the 30:2 ventilation strategy before intubation, when to consider endotracheal intubation during CPR, the time normally needed to complete intubation, the interruption time of compressions during intubation, whether to connect the ventilator immediately after intubation, the frequency of ventilation when using a bag-valve-mask, the choice of ventilator modes and parameters, and whether compressions lead to mistriggers or high pressure alarms on the ventilator machine. Both in-hospital cardiac arrest and out-of-hospital cardiac arrest brought into the hospital for further management were included.

Ethical statement

This study received approval from the Department of Ethics of the Peking Union Medical College Hospital before initiation. All participants consented to having the results of their surveys published.

Statistical analysis

Comparison of the data was undertaken by independent Student's *t*-test. Statistical analysis was undertaken using SPSS (IBM Corporation, Armonk, New York, USA).

RESULTS

Respondents

Questionnaires were e-mailed to 500 tertiary hospitals. A total of 438 physicians from all 31 provinces of Chinese mainland completed the questionnaire, including 344 emergency medicine physicians, 71 critical care physicians and 23 anesthesiologists (Table 1).

Survey results

Whether to start ventilation immediately during CPR

Out of 438 respondents with complete information, 258 started ventilations at the beginning of CPR; 39 performed compression-only CPR; 141 preferred compression-only CPR in the early stages and delayed ventilation. Of the 141 respondents who preferred delayed ventilation, 21 delayed for less than 3 minutes, 45 delayed 3–6 minutes, 52 delayed 6–9 minutes and 23 delayed 9–12 minutes.

Whether to strictly follow the 30:2 ventilation strategy

Before endotracheal intubation, among 399

Table 1. Basic information of respondents

Variables	Respondents (*n*)	Proportion (%)
Gender (male)	215	49.1
Age (years)		
20–25	31	7.1
25–30	84	19.2
30–35	86	19.6
35–40	128	29.2
40–45	61	13.9
45–50	29	6.6
50–55	19	4.3
Professional level		
Entry	126	28.8
Middle	202	46.1
High	110	25.1
Seniority (years)		
<3	46	10.5
3–5	50	11.4
5–10	116	26.5
10–15	117	26.7
15–20	62	14.2
>20	47	10.7
Training received based on		
AHA guidelines	113	25.8
ERC guidelines	10	2.3
Chinese Domestic	315	71.9
Specialty		
Emergency Medicine	344	78.5
Critical Care	71	16.2
Anesthesiology	23	5.3

AHA: the American Heart Association; ERC: European Cardiopulmonary Resuscitation Council; Professional level: professional level as qualified by the Chinese government.

respondents who gave ventilation during CPR, 331 strictly followed a 30:2 ratio, while 68 chose continuous compressions along with ventilations every six seconds.

When to consider endotracheal intubation during CPR and the time needed to complete intubation

Among 399 respondents who gave ventilation during CPR, 246 chose immediate endotracheal intubation, while 153 chose continuous 30:2 ventilations and intubation only if necessary. If immediate endotracheal intubation was needed, the time needed to complete intubation was as follows: 196 respondents reported within 2 minutes, 157 respondents within 2–5 minutes, 37 respondents within 5–10 minutes, and 8 respondents greater than 10 minutes. There was a significant difference in intubation time between the immediate endotracheal intubation group and the non-immediate endotracheal intubation group ($P<0.001$), with the immediate endotracheal intubation group much faster.

Interruption time of compressions during intubation

During intubation, the time reported for stopping compressions was: 113 respondents reported less than 5 seconds, 102 respondents within 5–10 seconds, 97 respondents within 10–30 seconds, 52 respondents within 30–60 seconds and 35 respondents over 60 seconds. There was a significant difference in compression stoppage time between the immediate endotracheal intubation group and the non-immediate endotracheal intubation group ($P<0.001$), with the immediate endotracheal intubation group much faster.

Frequency of ventilation using bag-valve-mask after intubation

Of the 399 respondents who gave ventilation during CPR, 15 respondents used a stopwatch to ensure 10 breaths per minute, 28 respondents used a feedback device to ensure 10 breaths per minute and 162 respondents counted to 6 to ensure 10 breaths per minute. Twenty-two respondents may give less than 10 breaths per minute (gave ventilation by experience), 129 respondents gave higher than 10 times per minute (gave ventilation by experience), and 43 cases chose to ventilate according to the patient's condition (with an uncertain breathing frequency).

Whether to connect the ventilator immediately after intubation

Of the 399 respondents, 73 respondents considered continuous bag-valve-mask ventilation, and 326 respondents would connect to a ventilator as soon as possible.

Choice of modes and parameters for the ventilator machine

Among 326 respondents who connected to a ventilator, 245 respondents used volume control (VC) mode, 59 respondents used pressure control mode and 22 respondents used pressure support mode. Target tidal volume selection included 53 respondents who selected 4–6 mL/kg, 235 respondents selected 6–7 mL/kg, and 38 respondents selected 7–10 mL/kg. Respiratory frequency selection: all 326 respondents chose 10 breaths per minute. Positive end-expiratory pressure (PEEP) selection: 24 respondents chose 0 cmH_2O, 204 respondents chose 0–5 cmH_2O, 87 respondents chose 5–10 cmH_2O, 7 respondents chose >10 cmH_2O, and 4 respondents chose "according to the patient's condition". The fraction of inspired oxygen selection included 21% for 6 respondents, 50% for 49 respondents, 100% for 218 respondents, and 53 respondents chose a concentration "according to the patient's condition".

Whether compressions during CPR caused mistriggers or high pressure alarms

After the parameters of the ventilator were set, 202 respondents found their ventilator often mistriggered, while 124 respondents didn't have a triggering problem. A total of 169 respondents found their ventilator often reported a high pressure alarm, while 157 (48.2%) respondents didn't.

DISCUSSION

Cardiac arrest and CPR have been given more and more attention in China due to the rise of rapid response and cardiac arrest teams with their greater emphasis on a structured and professional approach to resuscitation. However, there has been relatively few research on how to provide ventilations during CPR. The recommendations of popular guidelines and consensus statements lack detail in this area. In China, most hospitals send cardiac arrest team personnel out to receive basic life support and advanced cardiac life support (BLS/ACLS) training based on AHA, ECR, or the Consensus of Chinese Cardiopulmonary Resuscitation Experts. Our survey showed that physicians in most tertiary hospitals received CPR training based on the Chinese domestic consensus, while about a quarter of them received AHA CPR training,

while very few physicians received training based on the ECR guidelines.

Current guidelines recommend immediate ventilation once chest compressions begin. But our data showed that more than 40% of physicians chose delayed ventilation or non-ventilation. This result was similar to another international survey.[1] Advocates of compression-only CPR believe that compressions alone can provide enough passive breathing for sufficient oxygen delivery. However, several studies[2,3] have revealed that the tidal volume of ventilation caused by compressions alone is between 41.5 mL and 156 mL, while another study[4] reported 2 mL/kg, which is only enough to ventilate the lungs' dead space. However, if we give the patient high-flow oxygen during CPR, this can significantly reduce the actual lung dead space, and may give the patient enough oxygen to live.[5] Animal experiments confirmed that compression-only CPR alone would not lead to oxygen desaturation within 12 minutes due to the ventilation effect of compression itself, though carbon dioxide levels may increase.[6] For adults without asphyxia, the benefit of delaying ventilation for several minutes is still worth exploring. Our survey showed that respondents who advocated delaying ventilation did so for between less than 3 minutes to 9–12 minutes. At present, there are no relevant studies on the effects of delayed ventilation in CPR.

On the other hand, when cardiac arrest occurs, circulation relies heavily on chest compressions. Stopping compressions for any reason will immediately and rapidly reduce blood flow. In order to perform endotracheal intubation, many clinicians hold compressions. Similarly, the standard 30:2 strategy of stopping compressions for two ventilations may also leads to a significant reduction in blood flow. One of the solutions is continuous compressions with ventilations every 6 seconds before intubation. This approach was also mentioned in the 2017 AHA CPR guidelines update.[7] There is a large sample size study which showed that this method had no significant difference compared to the standard 30:2 strategy when considering survival rate or neurological recovery.[8] There are still concerns that ventilation during compressions may increase airway pressures and send gas into the esophagus, while ventilations during compressions may affect the generation of negative pressure in the thoracic cavity, which plays an important role in venous return and overall cardiac output.

Another widely debated topic is whether to intubate patients early or intubate only if necessary. The AHA guidelines suggest that intubation should be performed only if necessary (e.g. the airway cannot be maintained, or effective ventilation can't be given), while the ECR guidelines[9] do not clearly describe the preferred timing of intubation. Benoit et al[10] reported that early intubation before arriving at the hospital can improve the return of spontaneous circulation (ROSC) rate, survival to hospital arrival and recovery rate of neurological function, but does not improve the rate of survival to discharge. Studies finding against early intubation have been criticized for having obvious selection bias[11] or not specifically considering the proficiency of the provider performing the intubation.[12] Still, there is often a risk for gastric reflux and aspiration during bag-valve-mask ventilation, if the airway is not protected early through intubation; moreover, it is difficult to monitor end-tidal CO_2 without intubation, so it is very attractive for many skilled resuscitation teams to intubate as early as possible. Our survey found that nearly 67% of respondents chose immediate endotracheal intubation.

What is the impact of endotracheal intubation on compressions? In our data, half of the teams reported being able to perform an intubation in less than 2 minutes. Nearly 33% of the teams can control the compression stoppage time to less than 5 seconds. There were significant differences in intubation time and compression stoppage time between the immediate endotracheal intubation group and the non-immediate endotracheal intubation group. This result likely reflects a difference in endotracheal intubation skill levels in different hospitals. Based on the recommendations of the ECR guidelines, we have reason to support early endotracheal intubation in hospitals with a compression stoppage time less than five seconds.[13]

Current American and European guidelines recommend ventilation 10 times per minute after intubation and avoiding hyperventilation. However, there is no strong evidence to confirm that a rate of 10 per minute improves survival or neurological outcome more than other frequencies. The relevant evidence level is very low, and the recommendation intensity is weak.[14] For now, there are no recommendations on whether to continue bag-valve-mask ventilation or to connect a ventilator immediately after intubation, as there is no data to support one method over the other. Bag-valve-mask ventilation is a simple and practical method, but as to how to ensure 10 ventilations per minute, our survey found that only about half of the respondents can ensure this frequency of ventilation, whether using a stopwatch,[15] counting to 6, or using feedback devices. Nearly half of all respondents could not guarantee a ventilation frequency of 10

breaths per minute as required, and most of them had hyperventilation, which is consistent with prior studies.[16,17]

What about using a ventilator? At present, there are no recommendations for the best mechanical ventilation strategy during CPR. The most common settings are: VC mode, tidal volume of 6–7 mL/kg, PEEP of 0–5 cmH_2O, rate of 10/minute, and 100% oxygen, while turning off inspiratory triggers or adjusting the pressure trigger level to 20 cmH_2O or above, and having a high-pressure alarm set to 50 cmH_2O. However, the best ventilation modes are still being explored, including pressure-controlled ventilation (PCV), chest compression synchronous ventilation (CCSV), continuous positive airway pressure/pressure support ventilation (CPAP/PSV), and ultra-low tidal volume ventilation.[18]

Our survey found that there are a variety of ventilator parameter settings used in Chinese tertiary hospitals. From what mode to use, to Vt, PEEP or FiO_2, only the respiratory frequency setting was consistent. The affect of thoracic pressure on hemodynamics and survival rate in patients with CPR is still controversial,[19] and even if hypoxemia has an impact on the survival rate, experimental results are not consistent.[20,21]

Our findings showed that ventilator parameter settings for CPR patients are very variable, and the relevant ventilation recommendations in the guidelines are not very specific. There are many factors that need to be considered for proper ventilator settings: patient size and weight, comorbidities, the cause(s) of cardiac arrest and so on. But it is worth mentioning that more than half of surveyed physicians still report mistriggers and high-pressure alarms. Mistriggers often means higher respiratory frequencies are given. High-pressure alarms mean that lower tidal volumes are being delivered. This most likely is due to trigger pressures and high pressure alarms for ventilators not being effectively adjusted during resuscitation. This aspect of ventilator training is should be a productive area for added emphasis.

Limitations

Our study had several limitations. Due to its survey nature, we relied on voluntary reporting by physicians. We do not know for sure whether the respondents answered the survey according to their true practice. The significance and magnitude of this limitation is unknown. A second limitation is that the hospitals chosen are all large tertiary hospitals with established cardiac arrest teams, which may not represent the situation in all Chinese hospitals. Finally, although 88% of surveyed hospitals did respond, among the 12% of hospitals that did not return the survey, we discovered that these non-respondents were more likely to be smaller hospitals, whose physicians may have less CPR experience.

CONCLUSION

This study demonstrates a great amount of variability in ventilation strategies during CPR among tertiary hospitals in China. More specific CPR ventilation recommendations should be made available to improve standardization among physicians.

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Ethics approval: This study received approval from the Department of Ethics of the Peking Union Medical College Hospital before initiation. All participants consented to having the results of their surveys published.

Conflicts of interest: All authors declare that they have no competing interests.

Contributors: YCL designed the study; YMQ and HZ collected data; YCL, JW, and HDZ wrote the manuscript.

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