Ventilation strategies during out-of-hospital cardiac arrest: a problem that should not be neglected

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Abstract: The ventilation strategies of cardiopulmonary resuscitation (CPR) in patients out-of-hospital cardiac arrest (OHCA) is very important and has received more attention. In the past 10 years, many researches have focused on how to adjust the ratio and time of compression ventilation, minimize the frequency and times of chest compression interruption, and improve the success rate of restoration of spontaneous circulation (ROSC). The ventilation strategies that no ventilation and hyperventilation in the process of CPR are not supported by recent researches for their drawbacks and controversies, but passive ventilation (delayed ventilation) is strongly supported by a great deal of researches. There is debate about whether the use of advanced airway is recommended during the CPR process. How to define the best tidal volume, respiratory rate and fraction of inspired oxygen in CPR to ensure the best ratio of ventilation and blood flow will be the focus and difficulty of investigating ventilation strategies during CPR in further study.

Keywords: Ventilation strategies; out-of-hospital cardiac arrest (OHCA); cardiopulmonary resuscitation (CPR)

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Introduction

Cardiac arrest (CA) is the third leading cause of human death. In the United States, there are more than 400 thousand people suffering from out-of-hospital cardiac arrest (OHCA) annually, and the overall survival rate reaches 6–8% (1). In China, the success ratio of resuscitation for OHCA is even lower of only 1.3% (2-4). The main objective of resuscitation from CA is to restore oxygen supply rapidly to vital organs, such as the heart and brain, therefore, the core of cardiopulmonary resuscitation (CPR) consists of two parts: chest compression to maintain blood flow, and ventilation to maintain oxygenation. Since the publication of the American Heart Association (AHA) guideline in 2005, study on CPR focuses mainly on chest compression, and defibrillation, etc., but lacks of considerable attention on ventilation during CPR. In fact, the mode of ventilation, frequency and ventilation volume have great effects on the results of CPR, and more attention should be paid to.

A growing number of evidence suggests that many traditional resuscitation methods are inappropriate, chest compression is often interrupted by operations such as artificial ventilation and defibrillation in the actual process of CPR, beside, to ensure frequent interruption of ventilation, chest compression will reduce coronary perfusion pressure, all of which are strongly correlated with the poor prognosis of patients (5,6). Previous studies have shown that the intrathoracic pressure produced by ventilation varies inversely with the coronary perfusion pressure and the survival rate after CA. How about the processing of ventilation during CPR? Is ventilation required during CPR? How about the appropriate compression ventilation ratio? And the timing and mode of ventilation? All these questions need to be further studied.

The ratio and time of compression ventilation

In 2000, AHA changed the recommendation for ventilation ratio from 5:1 to 15:2. Later in 2006, AHA modified the guideline again and recommended a compression ventilation ratio of 30:2 for adults during CPR. The basis for the change in the guideline is that stopping chest compression during ventilation can cause interruption of blood flow, affect the success ratio of resuscitation, increase the ratio of compression ventilation at the expense of reduced pulmonary gas exchange, which in turn lead to increased cardiac output and elevated coronary perfusion pressure accordingly, thereby enhancing the success rate of restoration of spontaneous circulation (ROSC). Prior studies have suggested that continuous and uninterrupted chest compression may improve the success rate of ROSC (7,8). Recently in 2015, in the updated AHA guideline, it is reiterated that the rescuer should minimize the frequency and times of chest compression interruption, but no adjustment has been made to the ventilation ratio.

Does higher ratio of chest compression reduce the interruption of compression and improve the quality of resuscitation? In a recent study published in *the New England Journal of Medicine*, the status of chest compression was analyzed inpatients with non-traumatic CA from 114 emergency centers. Corresponding results showed that compared with patients with interrupted chest compression (the control group), higher survival rates and better neurologic outcome were not achieved in patients who had continuous chest compression (the intervention group). Hospital-free survival was significantly shorter in the intervention group than in the control group (mean difference, −0.2 days; 95% CI, −0.3 to −0.1; P=0.004) (9). The results contradicted previous studies which suggested that continuous chest compression could improve the survival rate of patients (7,8). The benefit of continuous chest compression mentioned in previous studies might be related to improvements of CPR technology (e.g., the frequency and ratio of compression), not just the effect of continuous chest compression alone. Although the current guidelines recommend increasing the ratio of ventilation, patients will benefit from many aspects with the continuous improvement and development of all aspects of CPR technology. Therefore, further clinical studies are needed to compare the actual clinical effects of continuous and intermittent chest compression.

No ventilation, hyperventilation or passive ventilation

No ventilation means that no additional ventilation is given during CPR. The support theory of no ventilation is the dilatation and contraction of the chest wall caused by mechanical compression of the chest wall. Chest compression forces the pulmonary air to flow out, while the chest wall retracts and the chest produces negative pressure, allowing the gas to enter the airway and the lung. Ventilation will be effective if the tidal volume is sufficient and greater than the dead space (about 2 mL/kg). Studies have found that uninterrupted compression has better neurologic outcome than conventional CPR using a compression ventilation ratio of 30:2. However, the limitations of these studies are that the advanced airway (endotracheal intubation) is opened, which is conducive to chest compression to provide adequate ventilation (10,11). However, some scholars believe that ventilation cannot be neglected during CPR. Despite the harmful effect of ventilation, the existing science does not support the abandonment of ventilation during CPR for chest compression. A porcine model of occluded respiratory tract was established by Dorph *et al.* (12), in their study, it was discovered that the prevention of passive inspiratory airflow by chest compression was more consistent with the pathophysiological changes in the human body during CPR. The effect of conventional CPR using the compression ventilation ratio of 30:2 and chest compression on ROSC was compared, and the results indicated that within the 1.5–2 min of the CPR in the no ventilation group, the arterial blood saturation was decreased, while the arterial oxygen content was capable of maintaining 2/3 of the normal level in the ventilation group. In addition, the duration of ROSC was shorter in the ventilation group than that in the no ventilation group, suggesting that ventilation was important during CPR.

Hyperventilation provides more positive ventilation than the guideline recommended. Under normal conditions, tidal volume of 8–10 mL/kg in the body can maintain normal oxygen supply and remove carbon dioxide (CO_2), however, during CPR, the cardiac output is only 25–33% of normal volume, the lung uptake of O_2 in the blood and the release of CO_2 from the blood are markedly reduced, and lower minute ventilation volume can maintain adequate oxygen supply.

With respect to the above, advanced airway ventilation recommended by AHA is the given of tidal volume of 6–7 mL/kg at the breathing rate of 8–10 times/min so that the arterial partial pressure of carbon dioxide ($PaCO_2$) can be remained between 40–45 mmHg. Hyperventilation is potentially harmful, which may increase CO_2 emissions, reduce CO_2 in the arterial blood, lead to contraction of the cerebral blood vessels, decrease cerebral arterial blood flow, and finally contribute to the occurrence of cerebral ischemia (13,14), hyperventilation should therefore be avoided during CPR. Meanwhile, previous evidence has shown that hyperventilation may contribute to increased intrathoracic pressure, impaired venous return, decreased coronary perfusion pressure, and lower survival (15-17).

Passive ventilation (delayed ventilation) can be referred to as cardio-cerebral resuscitation (CCR). In the first few minutes of OHCA, oxygen levels is remained at a certain level in the blood, additionally, the pulmonary blood flow is significantly reduced during CPR, and the minute ventilation volume required to maintain the normal ratio of ventilation and blood flow is also reduced, accompanied with decreased need for pulmonary gas exchange, reduced CO_2 production in the body, and decreased need for CO_2 removal. In this regard, theoretically, CPR is able to delay ventilation during the first few minutes which ensures continuous chest compression. As recommended by the guideline issued in 2015, at the beginning of CPR, emergency personnel can take advantages of three groups of 200 sustained compression cycles, in combination with strategies for passive oxygen delivery and assisted airway devices, so as to delay positive-pressure ventilation and to ensure continuous chest compression (18). Furthermore, CCR is an extremely effective resuscitation method that is relatively easy to be operated, and it is highly recommended that patients should be given continuous chest compression instead of ventilation at the early stage of recovery (19-21), which can significantly improve the prognosis of patients. A prospective study of OHCA evaluated the use of a continuous chest compression and high-flow oxygen during the chest compression suspension (Non-repetitive suction masks instead of providing positive-pressure ventilation), it was found that patients accepted this technique had a higher rate of hospital discharge (22).

Ventilation modes

The guideline updated in 2015 recommends that advanced airway should be used during CPR to ensure continuous chest compression (18). After starting chest compressions by the emergency personnel, the supraglottic airway (SGA) device (laryngeal mask) and the endotracheal tube (ET) can be used for advanced airways, which may conducive to promoting the direct entry of gas into the trachea and lungs, preventing the gas from entering the esophagus and stomach. Bag valve mask (BVM) is difficult to provide high quality ventilation, possible reason may be that the size and shape of patients' face are different. It is thus difficult to maintain a suitable mask seal, and the gas will leak through the mask into the atmosphere, eventually, the exact amount of tidal volume will not be guaranteed (23). Compared with ET, the SGA device has faster insertion speed to reduce the interruption time, which may result in higher quality of chest compression (24). Nevertheless, some studies have also demonstrated that the application of ET may lead to better prognosis than that of SGA device (25). Besides, other studies have also documented that some other advanced airway ventilation (chest compression synchronized ventilation, CCSV) can provide better oxygen supply and reduce the incidence of hypotension (26,27).

Complications and delayed compression may also occur during advanced airway setting, which may affect the prognosis of patients (28). A number of studies have discovered that there is no significant difference in neurologic outcome and survival outcomes between the application of SGA and ET in patients with OHCA using BVM device during ventilation (29,30). A large-scale prospective study in Japan was performed with the inclusion of 649,359 patients with OHCA who underwent either BVM or advanced airway management (ET or SGA), and the results showed that advanced airway management was significantly worse than BVM in neurological outcomes, thus confirming that the role of advanced airway management was worse than BVM in OHCA patients during CPR (31). At the same time, a meta-analysis of 388,878 patients with OHCA in 17 previous studies also found that advanced airway interventions were associated with lower long-term survival outcome, meanwhile, the short- and long-term survival rates of using SGA and ET were both lower compared with basic airway interventions (32). Currently, most studies suggest that prehospital tracheal intubation is associated with poorer neurological outcomes, and some studies have also found that prehospital tracheal intubation is correlated with an increased risk of death.

Expectation

In most cases of OHCA, ventilation is required, and the key to this issue is not whether to verify the existence of ventilation during CPR, but how to adapt the alveolar ventilation/blood flow ratio. During CPR, reduction of blood flow from the pulmonary vascular bed may result in hyperventilation, making ventilation/blood flow out of tune. How to define the best tidal volume, respiratory rate and fraction of inspired oxygen in CPR to ensure the best ratio of ventilation and blood flow will be the focus and difficulty of investigating ventilation strategies during CPR in further study.

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Footnote

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